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Final Report: Arctic Marine Radar Development
Phase I: Selection of Host Marine Radar

Prepared For:
Transportation Development Centre
Policy and Coordination Group Transport Canada

Prepared by:
Canarctic Shipping

January 1990

435892

The contents of this report reflect the views of Canarctic Shipping Company Limited and not the official view or opinions of the Transportation Development Centre.

Un sommaire en français de ce rapport est inclus avant la Table des matières.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 10105E	7184	

4. Title and Subtitle	5. Publication Date
Arctic Marine Radar Development Phase I: Selection of Host Marine Radar Final Report	January 1990
	6. Performing Organization Document No. CSCL _ 4872
7. Author(s) Charles Gautier	8. Transport Canada File No. D1460-146-8
9. Performing Organization Name and Address Canarctic Shipping Company Limited 1005-350 Sparks Street Ottawa, Ontario K1R 7S8	10. DSS File No. 14Sd.T8200-8-8532-A
	11. DSS or Transport Canada Contract No. T8200-8-8532/01-SD
12. Sponsoring Agency Name and Address Transportation Development Centre 200 René Lévesque Blvd. West West Tower, Suite 601 Montreal, Quebec H2Z 1X4	13. Type of Publication and Period Covered Final Report Oct 5/88 - Jan 10/90
	14. Project Officer Maurice Audette

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

16. Abstract

This report describes the selection and installation of a marine radar system suited to ice navigation. The need for such a system was identified during past projects where radar signals were marginally adequate. The goal of the project was the selection and installation of a radar system to support both, ice navigation and ongoing research.

A preliminary system was first designed from which requests for proposals were sent to prospective suppliers. Five systems were submitted for review; these were evaluated and a selection made. A system was ordered and the equipment shipped to Malta for installation. The preliminary design was modified to take into account the peculiarities of the selected system.

Technicians from Honeywell Sperry Canada assisted with the installation and the calibration of the final system. Special interface circuits were built as required to complement the installation. The final system provides 4 independent channels of radar data that can be accessed at any time through the Radar Display Selector. The four channels consist of: a Decca X-Band horizontal polarized, a Sperry S-Band horizontal polarized, a Sperry X-Band horizontal polarized, and a Sperry X-Band vertically polarized.

17. Key Words	18. Distribution Statement
Ship Radar, Marine Radar, Ice Navigation, SINSS, Cross Polarization, Radar Display, Arctic Navigation	Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	-	xii, 44 48 App	-

TDC/CDT 79-005
Rev 88

Canada

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada	2. N° de l'étude	3. N° de catalogue du destinataire
TP 10105E	7184	

4. Titre et sous-titre	5. Date de la publication
Arctic Marine Radar Development Phase I: Selection of Host Marine Radar Final Report	janvier 1990
	6. N° du document de l'organisme exécutant CSCL - 4872
7. Auteur(s) Charles Gautier	8. N° de dossier — Transports Canada D1460-146-8
9. Nom et adresse de l'organisme exécutant La Compagnie de navigation Canarctic Ltée 350, rue Sparks Suite 1005 Ottawa (Ontario) K1R 7S8	10 N° de dossier — ASC 14Sd.T8200-8-8532-A
	11. N° de contrat — ASC ou Transports Canada T8200-8-8532/01-SD
12. Nom et adresse de l'organisme parrain Centre de développement des transports Complexe Guy-Favreau 200 ouest boul. René-Lévesque Tour ouest, suite 601 Montréal (Québec), H2Z 1X4	13. Genre de publication et période visée Final 5 oct 1988- 10 jan 1990
	14. Agent de projet Maurice Audette

15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.)

16. Résumé

Ce rapport décrit la sélection ainsi que l'installation d'un radar maritime pour la navigation dans les glaces. Un tel système fut justifié au cours de projets antérieurs, durant lesquels la qualité des signaux radar laissait à désirer. Le but du projet était la sélection et l'installation d'un système radar capable de supporter la navigation dans les glaces, ainsi que la recherche dans ce domaine.

Un système de base fut conçu pour lequel des demandes de soumissions furent envoyées à plusieurs fournisseurs. Cinq systèmes furent soumis et évalués et un système fut commandé. La livraison fut effectuée à Malte, où l'installation eut lieu. Le système de base fut modifié pour prendre en considération les particularités du système choisi.

Deux techniciens de Honeywell Sperry furent envoyés sur place pour superviser l'installation et la mise en service du nouveau système. Des interfaces spéciales furent construites pour compléter l'installation. Le système final permet l'accès à quatre signaux radar indépendants, par l'intermédiaire du Radar Display Selector (RDS). Les quatre signaux disponibles sont: un Decca bande X polarisé horizontalement, un Sperry bande S polarisé horizontalement, un Sperry bande X horizontal, ainsi qu'un Sperry bande X polarisé verticalement.

17. Mots clés	18. Diffusion
Radar, Navires, Radar de bord, navigation des glaces, dépolarisation, affichage radar, navigation arctique, SINSS	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	-	xii,44 48 App	-

CDT/TDC 79-005
Rev 88

Canada

Acknowledgements

A number of individuals and organizations contributed to the success of this project. We would like to acknowledge Mr. Maurice Audette, Transportation Development Centre (TDC), for his support during this project.

Special thanks are extended to Daniel Rebibo, Honeywell Sperry, for his support before, during and after the installation of the radar system. Many thanks to Ms. Lise Avril of the same company for dealing so efficiently with equipment shipping difficulties.

Special thanks to Mr. Charles DeBonno, Malta Drydocks, for his help and the high degree of professionalism during the installation and modifications to the radar systems.

Many thanks to the Canarctic staff for helping to support the project while the installation was performed in Malta. These thanks are especially directed to Bob Gorman for dealing with the legal aspect of exporting the equipment.

This report was authored by Charles Gautier with editorial review by Alan R. Sneyd.

Executive Summary

This report describes the selection and installation of a marine radar system suited for ice navigation. This initiative, sponsored by the Transportation Development Centre, addressed the requirements identified during past projects, where the quality, variety and availability of radar signals were marginally adequate. The goal of the project was to select and install a host Arctic Marine Radar system to foster and support research in ice navigation.

A preliminary system was designed, out of which functional requirements were extracted. The information was sent, in the form of a Request For Proposal, to potential suppliers of radar systems. A total of five radar systems were submitted for review. The submitted documentation was evaluated and a selection was made. The choice of a radar system prompted a revision of the preliminary design, in order to take into account the peculiarities of the selected system. A system was ordered and arrangements were made to ship the equipment to Malta, where the M.V. Arctic was under refit.

Arrangements were made with Honeywell Sperry Canada, to have service personnel present at the time of installation. The Sperry technicians helped with the installation, the set up and the calibration of the new radar system. Malta Drydocks were contracted to perform most of the installation of the new radar, as well as the modifications to the existing system. Special interfaces were designed and built as necessary to complete the installation.

The resulting Arctic Marine Radar System consists of one dual polarized radar antenna driven by two X-Band transceivers, one raster scan display, a Radar Display Selector (RDS), and the existing complement of radar equipment that was on board before the installation of the new system.

Sommaire

Ce rapport décrit la sélection et l'installation d'un système de radar nautique adéquat pour la navigation dans les glaces. Ce projet, parrainé par le Centre de développement des transports, répond à un besoin identifié au cours de projets passés, au cours desquels la variété ainsi que la disponibilité des signaux radars laissaient à désirer. Le but de ce projet était la sélection et l'installation d'un système de radar de base appelé "Arctic Marine Radar". Ce système permettra de supporter et d'encourager la recherche dans le domaine de la navigation dans les glaces.

Un système de base fut conçu, duquel les spécifications techniques furent extraites. L'information fut envoyée sous forme de demande de soumission à plusieurs fournisseurs de systèmes radar. Au total, cinq systèmes furent présentés à Canarctic. Les systèmes furent évalués et une sélection fut faite. Le choix du système de radar nécessita la révision du système de base de façon à tenir compte des particularités du nouveau système. Un système complet fut commandé et transporté à Malte où le N.M. Arctic était en cale sèche.

Une entente fut conclue avec Honeywell Sperry Canada pour bénéficier de la présence de techniciens durant l'installation. Les techniciens de Sperry terminèrent l'installation du nouveau système, et procédèrent à la calibration et à la mise en marche du système. Malta Drydocks furent impliqués dans l'installation du nouveau système, ainsi que dans les modifications aux systèmes existants. Des circuits spéciaux furent construits pour compléter l'installation.

Le système résultant consiste en une antenne de radar à polarisation double, deux émetteurs radar bande X, une unité d'affichage à balayage horizontal, une unité de sélection de signaux radars (RDS), ainsi que la totalité du système radar présent à bord avant l'installation de celui-ci.

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Arctic Marine Radar Development
Phase I: Selection of Host Marine Radar

1. Introduction

Extensive research in the field of marine radar applied to ice navigation has been undertaken by a number of parties. During the course of this research, it became apparent that there is a requirement for the availability of a dedicated marine radar whose operating parameters can be changed at will without jeopardizing the operational safety of the ship. It has also became apparent that the operational requirements of an ice navigation radar are radically different from the requirements of normal navigation. The present project addresses the need for a low cost dedicated marine radar suited for both ice navigation and continued research.

1.1 Background

Extensive research on applications of marine radar has been undertaken in the past few years, mostly relating to techniques of precise navigation and navigation in ice covered waters (Robson, 1983; Viatec Resource Systems, 1985). Programs such as Canarctic's SINSS as well as Offshore Survey Ltd.'s RANAV have concentrated on developing new radar display devices to solve difficult navigational problems (OSL 1989; Canarctic, 1988). The Department of Fisheries and Oceans (DFO) in association with the Communications Research Laboratory of McMaster University have also undertaken research into ice and precise navigation, pioneering the use of dual-polarized marine radar for such applications (Edward O. Lewis, 1987). These research initiatives all utilize similar, specific radar components; a dual-polarized antenna, digital radar scan conversion, and advanced digital displays for navigation.

The operational experience of Canarctic in the Canadian high Arctic suggested that more cooperation between marine radar research programs was essential to the development of an efficient Arctic marine transportation system. Consequently, the Arctic Marine Radar Project was created to consolidate the complementary technologies of MARINE-VUE, the DFO sponsored CROSSBOW system and the TDC sponsored RANAV program.

Subsequently, the successful field trials of an experimental cross-polarized (Horizontal and Vertical) marine radar, developed by the Department of Fisheries and Oceans, onboard the M.V. Arctic, led Canarctic to purchase a cross-polarized antenna from Christiaan Huygens Laboratorium (CHL) of Holland. It was proposed that this antenna provide the basis for a radar system specifically designed for navigating in high Arctic conditions.

2. Objectives

2.1 Project Objectives

The primary goal of this project was to design and install an integrated radar system onboard the M.V. Arctic, which will suit operational, ice navigation, and research purposes. The new system must have the capability to drive advanced digital scan conversion displays, as imaging tools for ice and precise navigation. The specific objectives are as follows:

A) Define and specify all design considerations for the new system.

B) Design an integrated radar system with regards to the specific requirements.

C) Conduct a market review of existing radar components, and select the most cost effective and adaptable system.

D) Adapt the design to the selected radar and install the new system onboard the M.V. Arctic.

2.2 Scope

The design of the new radar system focused on resolving a number of previously identified operational and R&D problems. The most significant of these problems have been outlined below:

A) During the course of research conducted onboard the M.V. Arctic, a number of radar systems have been used and evaluated, both in terms of operational performance, and as a signal source to drive experimental prototypes. During the installation and testing of these prototypes, a number of deficiencies were identified, mainly in the area of signal compatibility and system performance. These deficiencies resulted from the use of standard commercial marine radar systems as host radars. These systems were not selected for technical characteristics but for navigation performance, and were therefore not well suited for research or use with a dual polarized antenna system. The new radar system is intended to eliminate this problem.

B) Ice radar technology developments require the availability of the highest performance systems, with capabilities covering the broadest range of applications. More sophisticated displays will be

developed, and as advancements are made in ice navigation technology, more stringent demands will be placed on the radar system. This was taken into consideration during the selection process.

C) In the past, radar display tests performed on the M.V. Arctic, required the host radar to be adjusted to specific settings. These settings were not always compatible with the navigational priorities of the pilots. In most cases, the signals to drive the displays being tested were not available. Operational independence of the new system, was made one of the primary design objectives.

D) S-Band radars have been considered inefficient in displaying ice features for the purpose of ice navigation. X-Band radars have characteristics that are more ideally suited for this purpose, and have been used almost exclusively for ice navigation. Conversely, the S-Band radar has been found useful in discriminating coastlines in ice covered waters. Even though regulations stipulate that a ship of the size of the M.V. Arctic must be equipped with two independent radars, they do not specify the operating frequency band. Both radars have specific applications, and one of each is found on most ships.

Should the X-Band radar become defective on ships so equipped, no backup would be available to optimally drive ice navigation displays. Given the importance of ice navigation, the new system must operate in the X-Band, and must be capable of supporting standard navigation, as well as other displays.

3. Methodology

Before a detailed description of this project is undertaken, the reader will benefit from a short description of the methodology used at different stages of completion. For clarity, the report is divided in three main phases; the system determination, the system selection, and the installation.

Canarctic Shipping benefits from extensive experience in the field of ice navigation radar. This experience is held in the form of hardware or concepts that have been developed over the years, and in the form of data collected during field trials. This information has been summarized to serve as the basis for the design of a new radar system. The summarized information is divided into 5 groups and formatted as design constraints. A complete listing of the constraints can be found in Appendix "A". The five groups are:

A) Operational Constraints: They summarize the information pertaining to the use of the radar system, for standard or ice navigation. These constraints were used during the functional design of the system, and during the evaluation of prospective systems.

B) Physical Constraints: They describe the desirable appearance and layout of the radar system. Akin to the operational constraints, but concentrating on the system implementation and layout, these constraints were mostly used during the determination of the layout.

C) Construction Constraints: Define the construction and design standards that the prospective equipment had to

meet. These constraints were mostly used during the evaluation of submitted systems.

D) Research Constraints: Were derived from past field trials and probable orientations of research in the field of Arctic marine radar technology. These were used mostly to define the technical characteristics of the selected radar system.

E) Regulatory Constraints: Were used only as an evaluation guide to determine the level of operational adequacy of the prospective systems. The fact is that radar system manufacturers build their systems to comply with the regulations.

Given these constraints, a draft design was developed. The design was forwarded to potential suppliers, asking for a bid and suggestions for the system's implementation.

Information received from the suppliers was evaluated and a preliminary ranking was made. Additional information was obtained from interviews with service personnel having experience with prospective systems. Discussions with selected suppliers resulted in a final selection and the order of a radar system.

The system design was adapted to the radar system which was eventually selected. Material needs for the installation were discussed with the supplier, along with the final details of the implementation. All the necessary material was assembled and shipped to the installation site at Malta. Arrangements were made to obtain technical assistance during the installation. Upon completion, all systems were tested and adjusted as required. The final acceptance was given and final installation drawings were produced.

4. Radar Selection

4.1 Preliminary Design

In order to provide prospective suppliers with a set of guidelines, a preliminary design was made (Figure 1).

The preliminary design was limited to the functional arrangement. Technical guidelines were also provided concerning operating parameters. A copy of the guidelines sent to the different suppliers is included in Appendix "B".

In this design, it was assumed that a full implementation would be necessary and possible. Full redundancy on the X-Band system was implemented. The control redundancy was implemented by providing alternate control stations for the new X-Band transceiver and the existing Decca transceiver. All signal sources were made available to all displays except for the S-Band unit, thus providing display redundancy. Power redundancy was provided at the power source, and not included in the preliminary design.

A few buffers were included throughout the design to provide adequate isolation and sufficient signal strength. It was assumed that most signal sources would be Decca compatible and no conversion would be needed anywhere.

4.2 Information Gathering

The preliminary design and specifications were sent to the following potential suppliers:

1) Racal-Decca Canada Ltd.
Missisauga, Ontario
Mr. Mike Ennis

2) Bendix Avelex (Furuno)
Richmond, B.C.
Mr. Paul Christensen

3) Dansk Marine (Kelvin Hughes)
St. Catharine's, Ontario
Mr. Ole Tang

4) McGuill Maritime
(Kelvin Hughes)
Montreal Que.
Mr. Bill Ellis

5) Canadian Marconi
Kanata, Ontario
Mr. Dave Halayko

6) Japan Radio Company (JRC)
New York, U.S.A.
Mr. Goro Usui

7) Raytheon Marine
Hudson NH, U.S.A.
Mr. Rick Wetmore

8) Canal Contractors
St. Catharine's, Ontario
Mr. Frank Sun

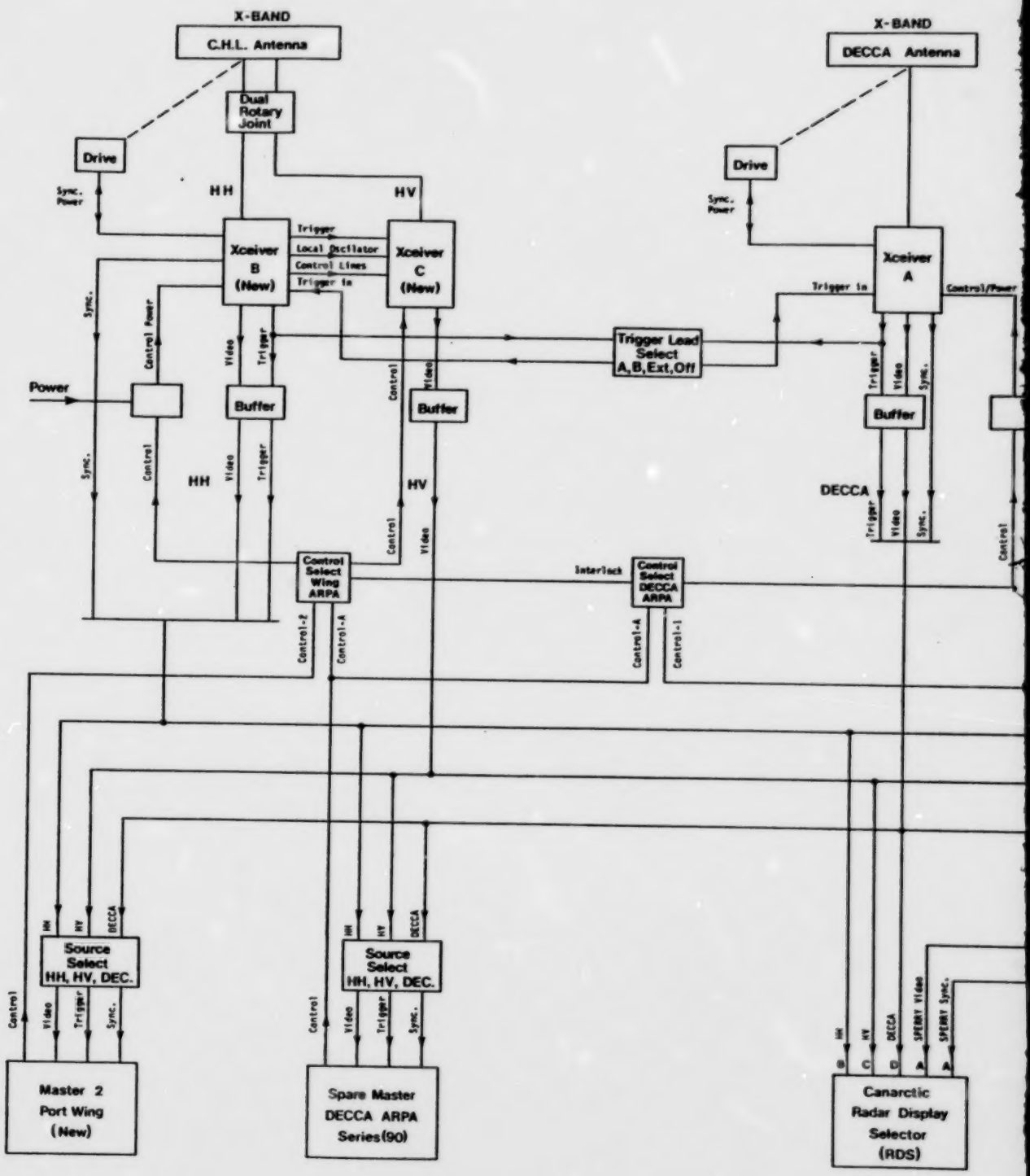
9) Honeywell (Sperry)
Montreal, Quebec
Mr. Emad Samwel

10) Socomar Inc.
Montreal, Quebec
Mr. Luc Hovington

11) Krupp Atlas Electronics
Bremen, Germany
Radar Sales Dept.

12) Radio Holland
Springfield NJ, U.S.A.
Mr. Leroy Marcroft

13) Anritsu Electric Co.
Tokyo, Japan
Radar Sales Dept.


X-BAND
C.H.L. Antenna
Dual Rotary Joint
Drive
Sync. Power
HH
HV
Xceiver B (New)
Xceiver C (New)
Trigger
Local Oscillator
Control Lines
Trigger In
Sync.
Control Power
Video
Trigger
Power
Buffer
Control
HH
HV
Control Select Wing ARPA
Control-2
Control-A
X-BAND
DECCA Antenna
Drive
Sync. Power
Xceiver A
Trigger In
Control/Power
Trigger Lead Select A,B,Ext,Off
DECCA
Interlock
Control Select DECCA ARPA
Control-A
Control-1
Source Select HH, HV, DEC.
Control
Video
Trigger
Sync.
HH
HV
DECCA
Master 2 Port Wing (New)
Spare Master DECCA ARPA Series(90)
SPERRY Video
SPERRY Sync.
Canarctic Radar Display Selector (RDS)

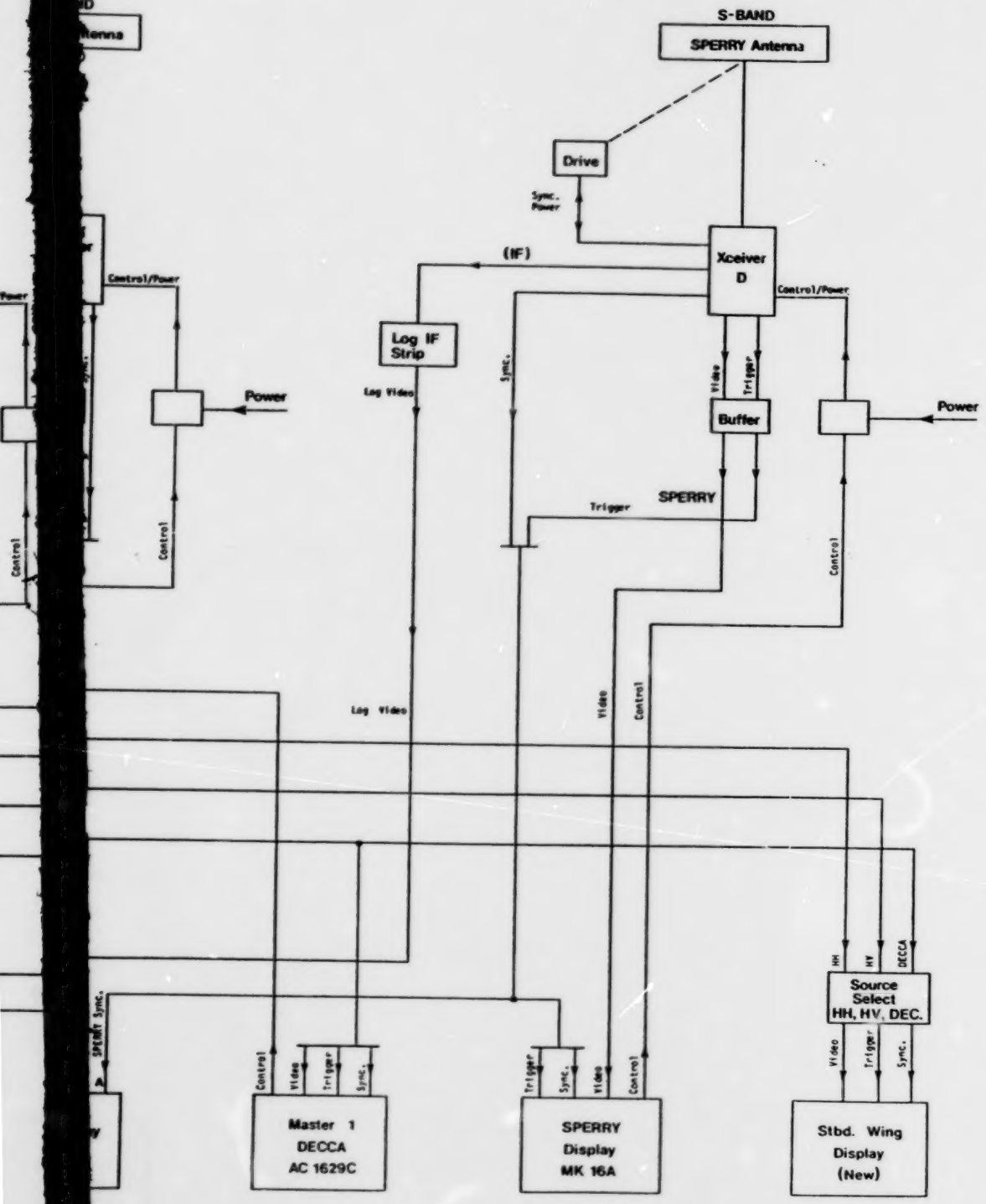


Figure 1

Multipurpose Integrated Radar System

A total of 5 different systems were submitted by different suppliers, representing the following manufacturers:

- Racal Decca (Master series 90)
- Raytheon (Pathfinder series S)
- Honeywell Sperry (Rascar)
- Canadian Marconi (LN66)
- Kelvin Hughes (HR "Concept" Radpack)

Many suppliers were not interested in getting involved with this project and declined to submit a system. Other suppliers did not have the technical personnel to handle this sort of application. Full technical documentation was received with all submitted bids, as requested. Two of the suppliers were initially reluctant to produce the technical documentation. Further explanations about the nature of the project, and the assurance of non-disclosure from Canarctic, led these suppliers to release the requested information.

A summary of the most important operational parameters of each radar is presented in Table #1.

Table 1. Comparative List of Radar System Parameters

RADAR PARAMETERS \ MANUFACTURER	SPERRY	DECCA	RAYTHEON	MARCONI	KHUGHES
Power	50	25	50	12	25
Pulse Width (min) (nS)	70	50	60	90	50
Pulse Width (max) (uS)	1	1	1	.5	.8
Receiver Noise Fig. (dB)	6	10	10	6.5	-
IF Frequency (MHz)	60	60	45	60	60
IF Band Width (max) (MHz)	17	20	25	15	-
IF Band Width (min) (MHz)	-	4	4	5	-
IF Dynamic range (dB)	90	96	70	-	-
Video Format	Log	Log	Log	Lin	Log
Video Polarity	Neg	Neg	Pos	Pos	Pos
Video Band Width (MHz)	6	16	20	-	-
Buffered Video	No	Yes	Yes	No	Yes
PRF (max) (KHz)	3.2	1.3	3.6	2.5	3.2
PRF (min) (KHz)	.64	.65	.90	.80	.80
External PRF	No	No	Yes	Yes	No
PRF Rate Protection	No	No	Yes	No	No
Blanking Input	Yes	No	No	No	Yes
Delay on Range Change (mS)	200	No	300	No	.5uS
Tuning Control (Manual, Auto)	M/A	M	M	M	M
No. of Supply Voltages	6	4	10	9	9
Over/Under Voltage Protection	Yes	N.A	Yes	Yes	No
No. of Connections to DCU	17	21	26	37	21
Xceiver Supply Source	Int	Ext	Int	Ext	Int
Magnetron Heater Voltage	Var	Fixed	Var	Var	Var
Scanner Motor Feed	AC	DC	AC	DC	DC

4.3 System Selection

In order to evaluate the submitted systems the following main criteria were used, in order of importance:

1) Transceiver power output
2) Receiver front end noise level, video signal format and bandwidth

3) Construction standards and reliability
4) Technical support and documentation
5) Quality of displays
6) Azimuth signal format and general interfacing requirements

4.3.1 Power considerations

No more than 50 Kw can be transmitted through the vertically polarized section of the CHL antenna rotary joint (Appendix C). Conversely, the maximum power allowable through the horizontal polarized section is 200Kw. In order to allow transmission either on the vertical or horizontal channel with the same transmitter, the maximum power output for the new radar has been restricted to the 50 Kw level. Furthermore, at higher power levels, a risk exists that sufficient power can be reflected back through the vertical channel to damage the rotary joint.

Maximum performance in range requires the utilisation of a transceiver with nominal power close to the maximum allowable value. Our experience with X-Band radars, is limited to the 25 Kw range and it is not known to what extent a power increase will provide an advantage over the 25 Kw power level used to date. The range at which useful signals from the ice surface can be received was limited to 3Nm in the old system. This limit is primarily imposed by effects of the radio wave grazing angle, which is a function of effective antenna height. It is structurally difficult to increase the antenna height and consequently increase the range in this manner.

At very low grazing angles, targets located at the limits of the useable range will generate very weak echoes that fall below the background noise level. Increasing the power level would

raise the level of the echoes of these targets above the background, thus increasing the useful range of the radar.

4.3.2 Noise Figure Considerations

The noise figure of the receiver has an effect as important as an increased power level. Noise contributions by the receiver, effectively swamp signals that are barely above background noise level to begin with. A lower noise figure allows the discrimination of weaker echoes. The gain of the CHL antenna is lower than the Decca antenna used up to now. A lower gain, means that the signal to noise ratio performance of the CHL antenna is lower than the Decca antenna. To compensate, a low noise figure receiver should be used. Any margin remaining beyond the compensation level, will contribute to a better system performance.

4.3.3 Signal Bandwidth Considerations

The area of main interest for the Arctic Marine Radar is close range ice detection and imaging. At close range, the resolution required to display all incoming information is much higher than what is required at far range. Higher resolution entails higher video signal bandwidth. To illustrate these concepts, the following calculations describe radar parameters at far and close range:

The required signal resolution is based on a raster scan display of 512 x 512 pixels. The range of a radar display is expressed as the radius (in units of nautical miles) from the centre to the periphery of the display and is divided in 256 equal parts (256 pixels from the centre to

the edges of the display). For example, a range of 12 nautical miles implies that each pixel represents a length of 12/256= .04688 nautical mile (87 meters). A range of 1 nautical mile therefore yields 7.25 meters/pixel.

The received radar signal is related to target distance by a ratio of 6.67 nS(nano seconds)/meter (radio wave propagation). For a range of 1 nautical mile, one pixel therefore represents a period of 6.67 x 7.25= 48.36 nS. For a 7.25 meter feature to be represented on the display, the neighbouring pixels around the one representing the feature must be off. Two consecutive pixels can therefore be taken as the two half cycles of the incoming analog radar signal (the negative part of the sine wave represented by one dark pixel, while the positive part is represented by an adjacent bright pixel). If two pixels represent one cycle, the required video bandwidth is therefore the inverse of total time required for two pixels; in this case, 1/(2 x 48.36 nS)= 10.34 MHz. Correspondingly, the maximum radar pulse length allowable for this range is equal to the time equivalent of the minimum target size, thus 48.36 nS.

For higher ranges, such as the 12 Nm range given above, the video bandwidth (using similar calculations) would be 860 KHz with a maximum pulse length of 580 nS. In practice, the video bandwidth is kept at a minimum of approximately 5 MHz, while the maximum pulse width is 1 nS. The maximum pulse width is a function of magnetron capacity and life expectancy, while the minimum video frequency is usually a function of circuit complexity.

From the above calculations, it is easy to justify the need for high video bandwidth and short radar pulses, especially if

close range high definition images of the ice surface are the ultimate goal. The selection of the new radar was strongly biased by the availability of minimal bandwidth, at least all the way through the IF strip. A bandwidth corresponding to the maximum resolution of a .75 nM display (14 MHz) was considered a minimum requirement for the IF strip. A bandwidth corresponding to the maximum resolution of a 3 nM display (3.5 MHz) was considered a minimum requirement for the video signal. The minimum pulse width required was chosen to correspond to the .75 nM display requirement which is 36 nS.

None of the radars under consideration met the requirement for minimum pulse width. The requirements for this item were thus reduced since major hardware modifications would be necessary in order to achieve the required pulse length. A minimum pulse length of 140 nS corresponding to the 3 nM range was thus specified.

4.3.4 Azimuth Transmission Considerations

There are three widely used azimuth transmission methods: Synchro transmission, Resolver transmission, and Pulse transmission. For the Synchro and Resolver transmissions, the reference signal frequency is usually 400 Hz but could be 4,000 Hz or 60 Hz, depending on the manufacturer. Pulse transmission can be any number of different standards, and there seems to be no consensus among manufacturers. Each manufacturer has chosen what he believed to be the most adequate, consistent with their design and the required resolution. The standard chosen for the Arctic Marine Radar, is Synchro transmission with a 400 Hz reference.

Almost all systems can be adapted one way or another to accept Synchro transmission. Converters are widely available to convert from synchro to digital, Synchro to Resolver, or Synchro to linear and the reverse is also true. However, no manufacturer has adopted the same Pulse transmission standard and a custom converter would have to be built for each application. The SINSS system uses two radar signal sources. The use of pulse transmission for antenna position transmission, would complicate the task of switching over from one signal source to the other. Furthermore, the Radar Display Selector (RDS) unit used to select the signal sources, will only operate with synchro signals.

4.3.5 Evaluation

All submitted radar systems were reviewed and the technical manuals carefully studied. From this analysis, a subjective evaluation was made on a number of specific points. Table 2 summarizes this evaluation. Additional criteria of a general nature were derived from each set of constraints. Interviews with radar technicians complemented the evaluation of the technical support. Users of different radars were consulted about their systems and their level of satisfaction with regards to the above listed evaluation criteria.

Table 2. Comparative Radar Systems Evaluation

MANUFACTURER / EVALUATION CRITERIA	SPERRY	DECCA	RAYTHEON	MARCONI	KELVIN HUGHES
Technological Level	.9	.5	.7	.7	.7
Modularism	.8	.8	.6	.9	.8
Ease of Repair	.8	.7	.6	.7	.8
Auto-check Features	.8	.5	.9	.7	.7
Technical Support	.7	.6	.8	.8	.6
Service Availability	.7	.7	.8	.6	.7
Parts Availability	.7	.8	.9	.7	.7
Documentation Quality	.8	.5	.8	.8	.8
Technician's Appraisal	.8	.5	.7	-	.7
Cost	.7	.8	.8	.6	.9
General Appraisal	.9	.5	.8	.6	.7
	.78	.63	.75	.71	.74

(Scale of 0 to 1).

Several interviews of radar technicians were conducted to complement the evaluation of the different radar systems. Not much information could be obtained for the Canadian Marconi or Kelvin Hughes systems. These systems are not widely used in North America and few technicians had worked on them. Conversely ample information was available for the remaining systems and can be summarized as follows:

Racal Decca: These systems are reported as being very unreliable even though some units will function without problems for years. The documentation is

very poor and technical support is difficult to get. Units are not easy to service and parts are expensive. Very little self protection has been built into the system and certain faults can lead to massive circuit damage.

Raytheon: These systems are fairly reliable but very complex. Technical support is excellent and documentation is very adequate. Parts can be a problem to find, especially in foreign ports. These radars have a very high degree of self protection, and faults generally cause very little damage. Servicing is physically easy but the complexity of the units make trouble shooting difficult.

Sperry: These systems are built with state of the art technology. The design has been completed very recently and takes advantage of the latest technological developments. The resulting implementation provides the best combination of performance, complexity and reliability. Servicing is easy and documentation is very good. Technical support is adequate and available in most major ports. Spare parts are expensive but readily available. This system came highly recommended.

Based on the above evaluation, the Sperry system was selected as the most suitable for the Arctic Marine Radar. The decisive factors were the high power output, the low noise receiver front end, and the state of the art implementation.

5. System Design

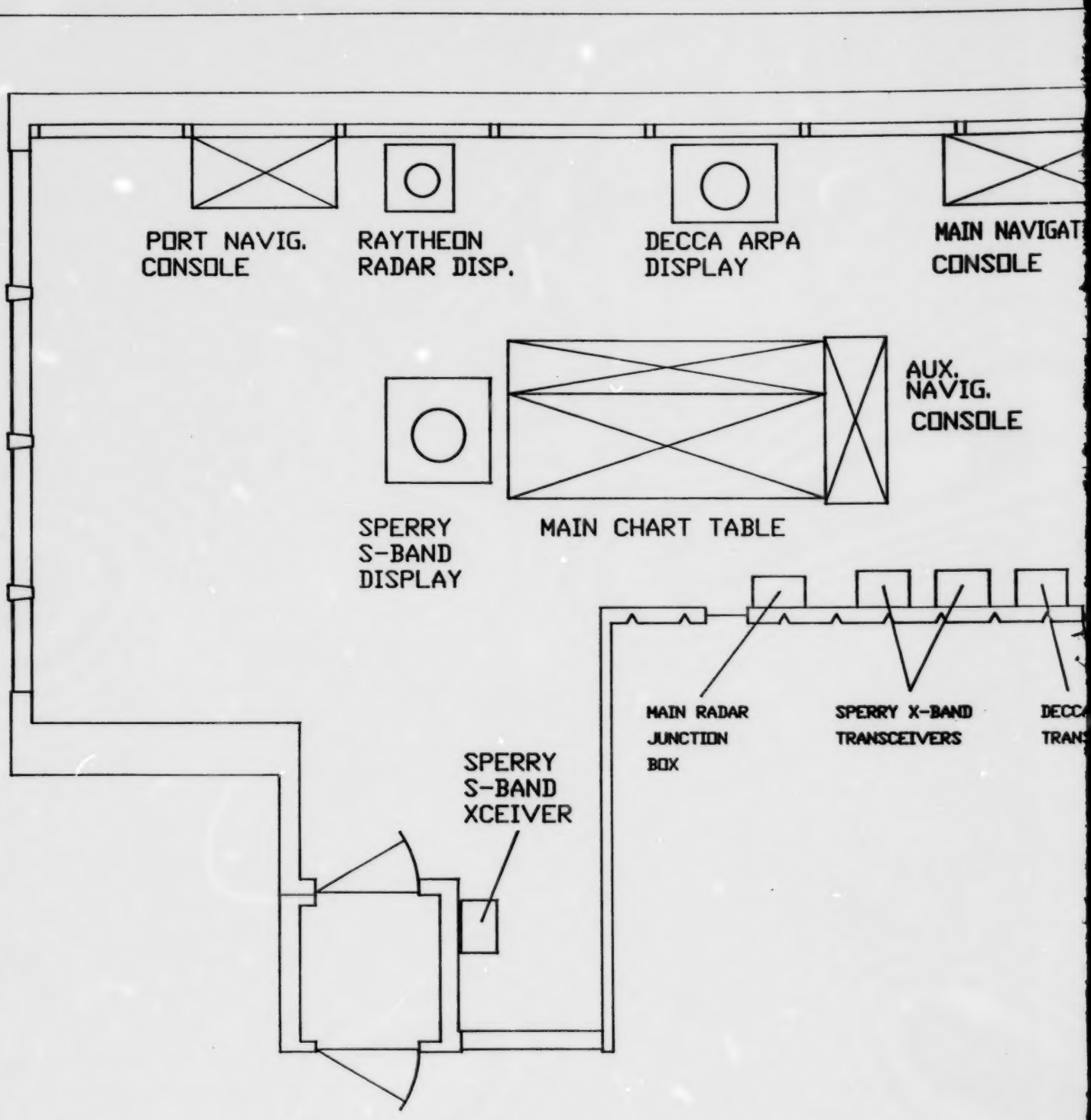
The radar system was designed primarily based on operational, research and regulatory constraints. Operational constraints provided input for the number of displays, their relative capability, the level of interconnection, and the general layout. Research constraints on the other hand, were the determinant source for technical aspects of the design. The definition of signal parameters and transmission conventions were also derived from the research constraints. Regulatory constraints were used equally for design and selection. The level of interconnection and other design parameters were directed by compliance to regulations.

5.1 Physical Layout

The most important aspect of the layout was the location of the displays. Three goals guided the design of the layout:

- Reduce the distance between components of individual systems
- Provide equal information display capability on either side of the bridge
- Create the least disruption to the existing systems, to reduce installation costs

Figure 2 shows the location of all the Arctic Marine Radar components on the bridge of the M/V Arctic. The location of these components was addressed in the "SINSS Ice Navigation Console Phase II; Console Implementation and Bridge Upgrade" project, undertaken concurrently with this project and are discussed in the final report. Nevertheless the choice of the layout is consistent with related constraints defined in Appendix A.


PORT NAVIG.
CONSOLE
RAYTHEON
RADAR DISP.
DECCA ARPA
DISPLAY
MAIN NAVIGAT
CONSOLE
AUX.
NAVIG.
CONSOLE
SPERRY
S-BAND
DISPLAY
MAIN CHART TABLE
MAIN RADAR
JUNCTION
BOX
SPERRY X-BAND
TRANSCEIVERS
SPERRY
S-BAND
XCEIVER

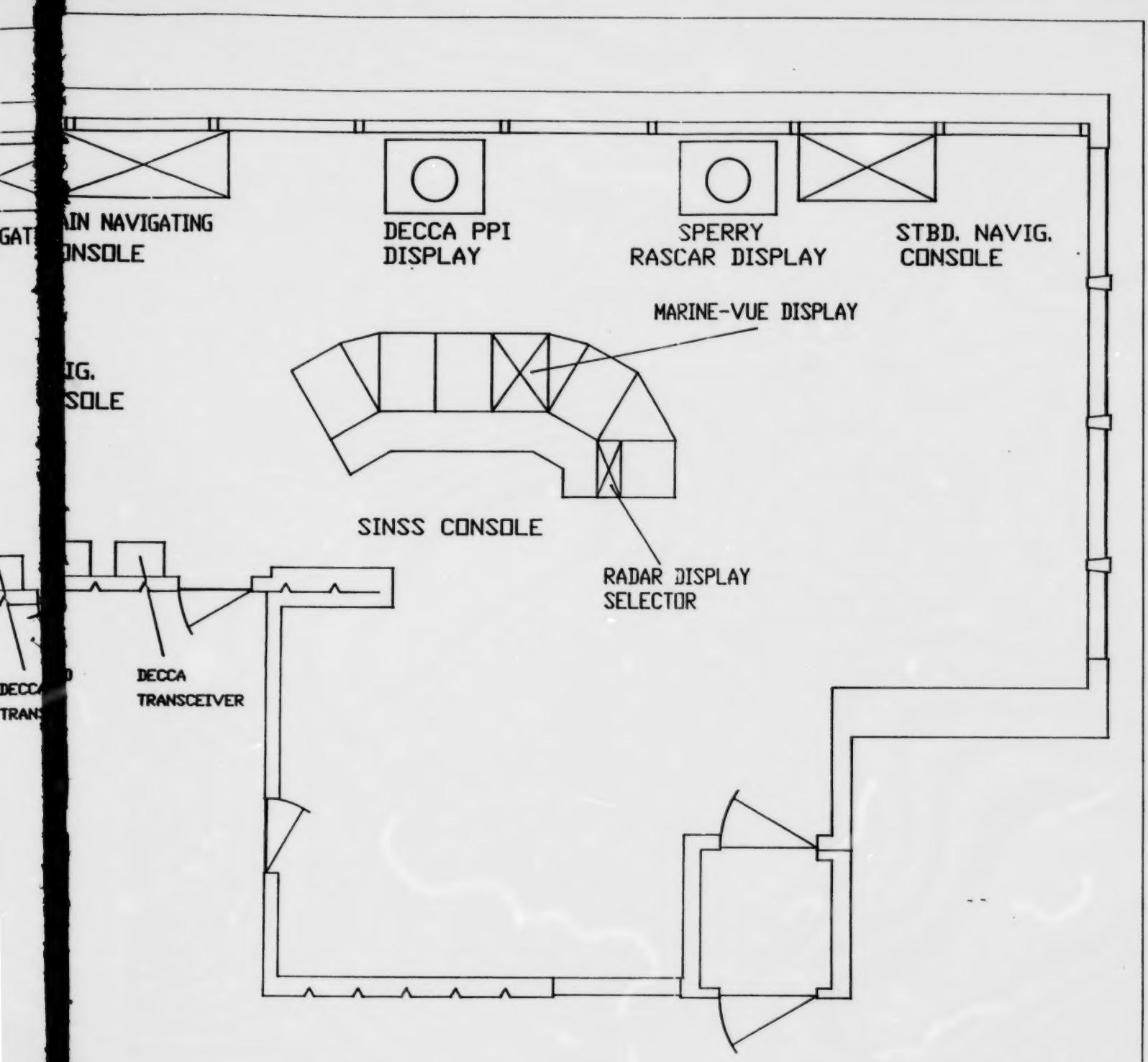


Figure 2
M.V. Arctic Bridge

5.2 Functional System Design

The functional design had the following goals:

- Provide equal information display capability on either side of the bridge
- Provide adequate redundancy to comply with all regulations
- Maintain the new radar as independent as possible from the rest of the radar system
- Provide maximum expandability and flexibility for future projects

The preliminary functional design was overly complicated and comprised the highest level of redundancy and interconnections (Figure 1). This high level of complexity forced the manufacturers to provide a better proposal, and justified the demand for more detailed information than would have normally been provided.

Once the selection was made, the design was rationalized and adapted to the new radar (Figure 3). Substantial reductions in redundancy and interconnections were made. It was recognised that the new system comprised three independent radars, which in itself constitutes enough redundancy. Maximum independence was maintained by minimizing the number of interconnections between the systems. The fact that the new radar is intended to be kept independent of the others, allows for maximum flexibility for modifications and dedicated operation. Regulations require two independent radars at all times, and the Decca X-Band and the Sperry S-Band fulfil these requirements, while the new X-Band radar can be used for research purposes.

With respect to the revised functional design in Figure 3, the M.V. ARCTIC radar system comprises 3 different radars: the new X-Band radar, the Decca X-Band radar, and the Sperry S-Band radar. The Arctic Marine Radar system proper, is restricted to the dual polarized antenna, the driving transceivers, the associated daylight display, and the RDS unit. The other components allow the information to be displayed at different locations on the bridge, and mainly respond to operational requirements. Each component is further described below:

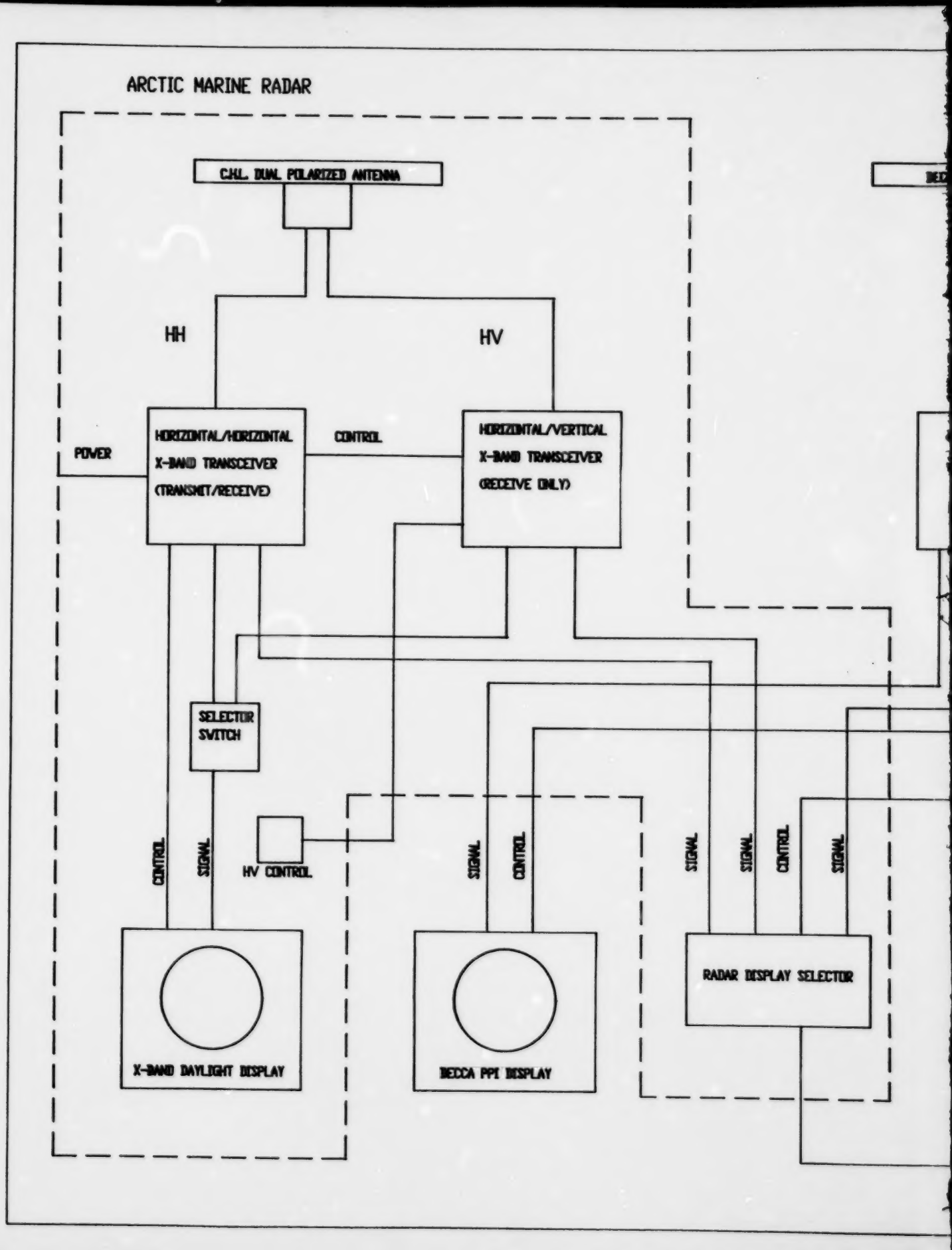
A) Dual Polarized Radar

Two transceivers drive the dual polarized antenna. One of the transceivers (HH) transmits and receives, while the other transceiver (HV) receives only. This basic operating configuration can be altered and transmitting can be done on the vertical polarization instead of the normal horizontal mode.

In order to make the two X-polarized signals available at all times, an independent set of controls was implemented for each transceiver. The HH controls are located on the display. The controls for the HV transceiver have been mounted on the side of the display unit and consist of the gain control, STC control, and manual tuning control (with indicator). The reduced number of controls for the HV transceiver results from the fact that it does not transmit.

B) Decca X-Band Radar

The Decca radar consists of one standard transceiver and antenna, driving two Decca PPI displays. One of the PPI displays is a standard function unit, while the second one is a full ARPA (Automatic Radar Plotting Apparatus). The two displays are driven by a standard Decca buffer unit.


ARCTIC MARINE RADAR
C.H.L. DUAL POLARIZED ANTENNA
HH
HV
HORIZONTAL/HORIZONTAL
X-BAND TRANSCEIVER
(TRANSMIT/RECEIVE)
POWER
CONTROL
HORIZONTAL/VERTICAL
X-BAND TRANSCEIVER
(RECEIVE ONLY)
SELECTOR
SWITCH
CONTROL
SIGNAL
HV CONTROL
SIGNAL
CONTROL
SIGNAL
SIGNAL
CONTROL
SIGNAL
X-BAND DAYLIGHT DISPLAY
DECCA PPI DISPLAY
RADAR DISPLAY SELECTOR

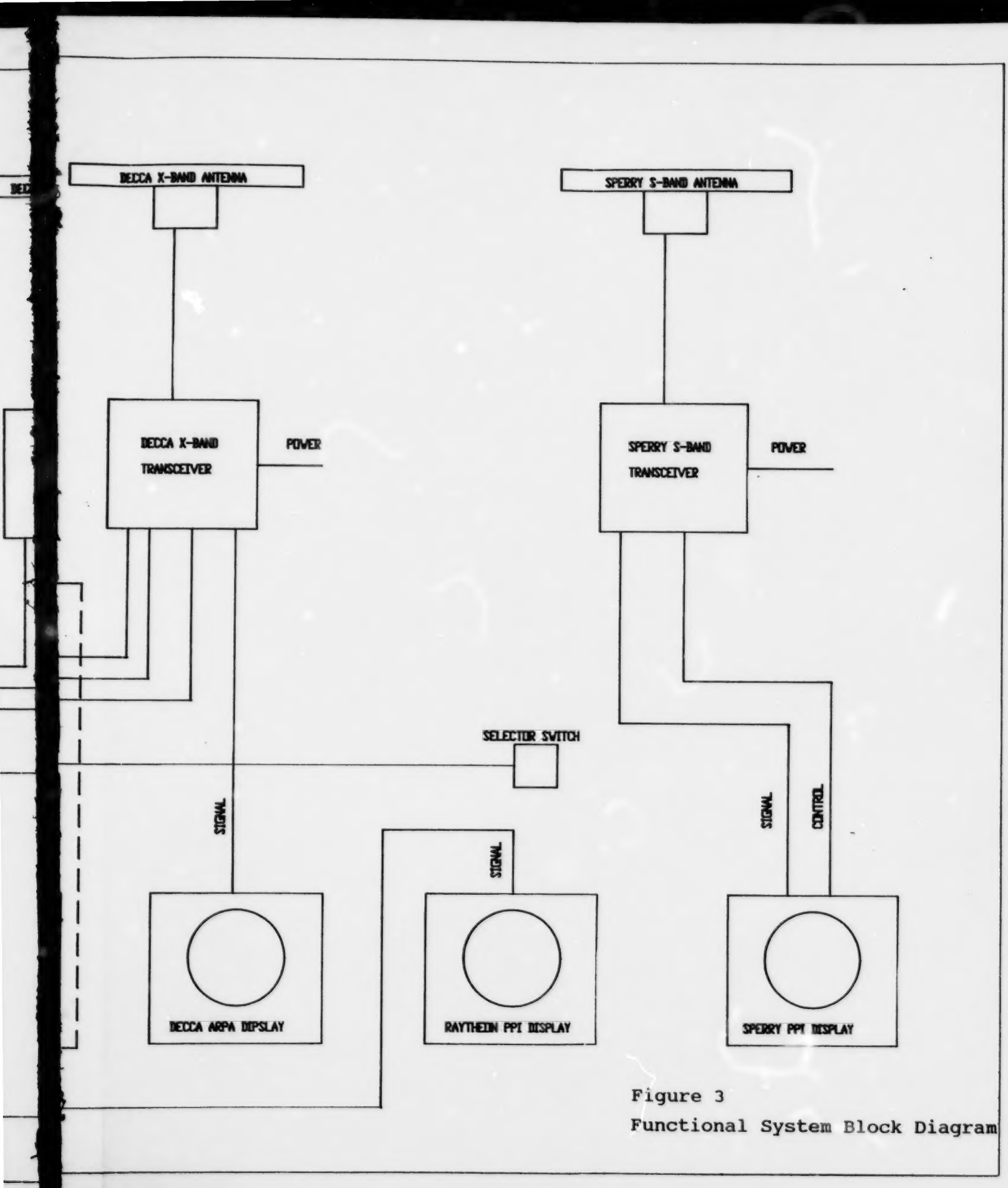


Figure 3
Functional System Block Diagram

This buffer unit is seen by the transceiver as one standard load. Since the transceiver is capable of supplying two standard loads, the RDS could be connected to the transceiver without the need for an extra buffer. The transceiver unit is controlled from the standard PPI display located on the starboard side of the main console. Any changes in range and pulse length, will affect the signal fed to the ARPA unit on the port side of the main console. The changes will also affect the signal fed to the RDS unit.

C) Sperry S-Band Radar

The Sperry S-Band radar is configured as an independent unit with one single display connected to a standard transceiver and antenna. This radar is part of the original ship's equipment and is still operational. A redundant interswitching unit was removed during the bridge upgrade project, considerably simplifying the installation.

D) Raytheon PPI Display

The Raytheon PPI display was recouped from a former bow radar installation. The display has special interface requirements, that are not compatible with the standard Decca signals used throughout the Arctic Marine Radar system. The RDS unit comprises an output that is configured to drive a Japan Radio Company (JRC) display unit. Since the JRC signal format is similar to the Raytheon signal requirements, it was decided to use the RDS unit to drive the Raytheon PPI display, and only slight modifications were necessary to the RDS unit, as well as the Raytheon display itself. A remote control switch was installed near the display to control the RDS unit.

5.3 Technical Design

The technical design consists of the circuit connections and special devices or interfaces necessary to implement the functional design. In addition to the special devices or interfaces, circuit modifications to certain devices were necessary to complete the implementation. The special devices/interfaces and circuit modifications are described below. The system cabling diagram is presented in drawing 63-E-80/A in Appendix D.

5.3.1 Raytheon Sampler Interface

The azimuth signal format for the Raytheon PPI display is different than formats used for other PPIs. In order to artificially generate the necessary azimuth information from the synchro signals generated in the CHL antenna, a number of adaptations were made:

1) - The RDS was modified to generate the 900 Hz resolver signals from the standard synchro sources available on the bridge. A full description of the RDS modifications can be found in Appendix D.

2) - A special adaptor was designed to generate the sampling signals needed by the Raytheon display to allow the use of the standard 900 Hz reference as generated in the RDS. A full description of the unit can be found in Appendix D.

3) - Circuit modifications were made in the Raytheon PPI display to route the signals adequately. Some connections were necessary to deactivate security

circuits normally used in a fully configured Raytheon radar. These circuit modifications are discussed further in Appendix D.

5.3.2 Synchro Driver

The CHL antenna was delivered fitted with a standard synchro azimuth transmission system. The new Sperry radar cannot accommodate a synchro transmission system and normally uses pulse transmission techniques and is therefore not equipped to drive a synchro transmitter. In order to drive the azimuth synchro fitted in the CHL antenna, a source of 400 Hz AC power is required.

One option, that was seriously considered, was to drive the new synchro using the synchro reference signal from the existing Decca radar. It was decided, for reasons of autonomy, that a separate synchro reference signal would be used. A synchro reference driver was designed and installed. A full description of this unit can be found in Appendix D.

5.3.3 Video and Trigger Buffers

The full design, as shown in Figure 3 does not necessitate the use of signal buffers. The number of loads the system has to support at each output is limited to 2. The exception to this is the Decca system, having 3 loads. These three loads are handled by a buffer unit that remained from the old installation.

Subsequent modifications and the addition of more equipment may require the signals to be buffered. The structure of the system is such, that such buffers can be easily installed, without much circuit modifications.

5.3.4 Azimuth Pulse Transmitter

As mentioned before, the CHL antenna is equipped with a synchro azimuth transmission system that is not compatible with the Sperry system requirements. In order to supply the Sperry system with azimuth information, two options were available:

- Design and build a synchro to pulse converter
- Install a pulse transmitter in the antenna scanner

Because of simplicity and accuracy, the second option was chosen. The availability of a second azimuth transmission signal will allow high precision measurements of the scanner angle, and will make the system more flexible. Section 6.1 discusses further the CHL antenna modifications and installation.

6. Installation

The total radar system was shipped for installation to Malta. Substantial difficulties involving customs, freight forwarders and the airline companies, developed during the shipment. Delivery of the equipment was made on January 30th, 1989, with only one week left before the ship's departure from drydock.

Arrangements were made to have technical assistance from Sperry during the installation of the radar system. Two technicians were dispatched by Sperry to assist during the installation. Sperry agreed to cover all charges for one technician, given the special nature of this project. The two technicians were on location for a period of one week, during which the installation and commissioning was completed.

6.1 CHL Antenna Installation

The main mast was prepared and a mounting base fabricated. A dual wave guide was installed and cables routed as required. The antenna was assembled, hoisted in position and fastened to the mounting base. Figure 4 shows the completed antenna installation.

Figure 4: CHL Antenna Mast Installation

A number of modifications and adjustments were made to the antenna in order to complete the installation:

- The scanner is fabricated to be installed on a mast where the waveguide is internally mounted and does not normally require sealing at the base. A special gland was fabricated to seal the scanner base at the point of waveguide entry in order to protect the azimuth transmission devices mounted inside. Figure 5 shows the special gland used for the installation.

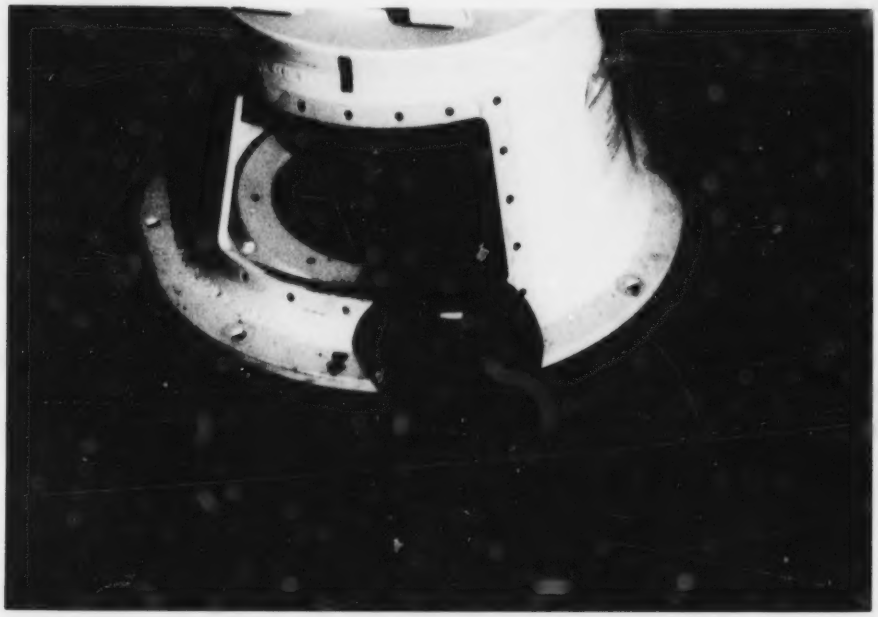


Figure 5: CHL Antenna Base Gland

- Special brackets as well as a gear wheel were needed to complete the installation of the azimuth pulse transmitter inside the scanner. Figure 6 shows the synchro azimuth supplied with the CHL antenna, while Figure 7 shows the pulse transmitter and gearwheel to be mounted in the scanner. The lower tip of the pulse transmitter can be seen in Figure 5.

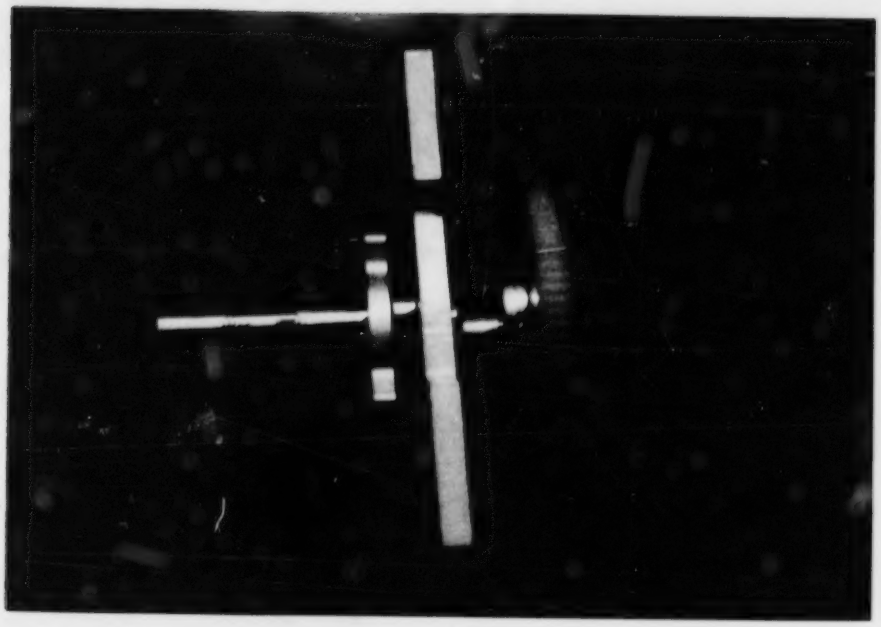


Figure 6: CHL Antenna Synchro Azimuth Transmitter

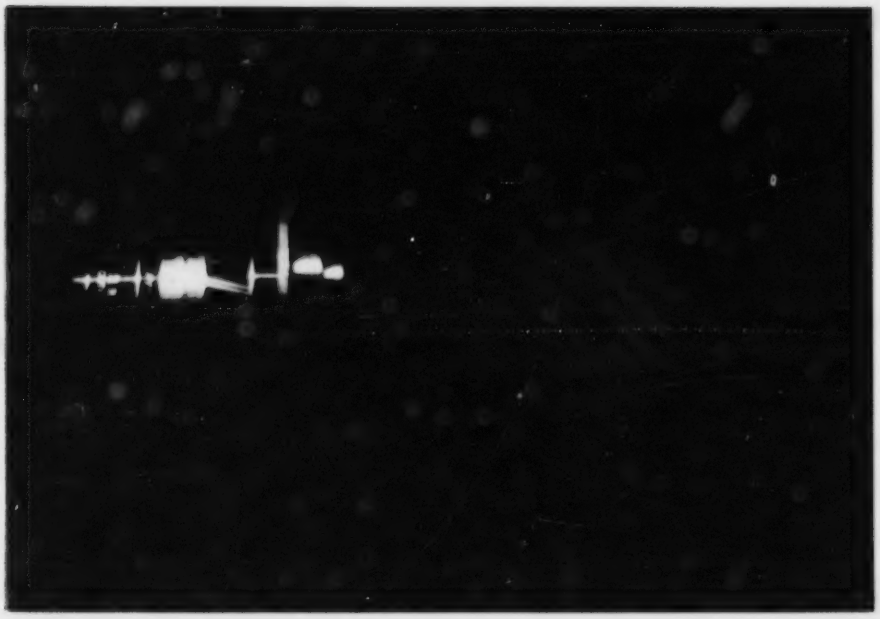


Figure 7: Sperry Azimuth Pulse Trnasmitter

- The antenna waveguide connection flange did not lineup with the installed waveguides and the flange had to be turned by 90°. This procedure, although not described in the antenna technical reference manual and inferred from the mechanical drawings, significantly simplified the installation of the waveguide. Figure 8 shows the antenna waveguide flange at the bottom of the scanner. The adjusting collar screw (horizontal recessed) is clearly visible at the flange base.

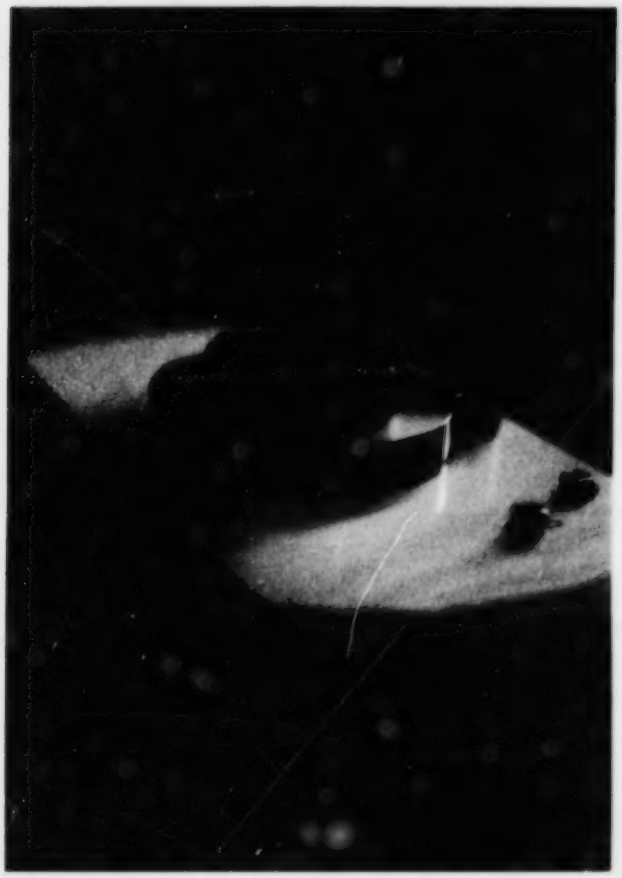


Figure 8:
CHL Antenna Waveguide
Connection Flange

6.2 Transceiver Installation

The transceivers were installed on the aft bulkhead of the bridge. No special difficulties were experienced during the installation, other than the inadequacy of the power supply. The transceivers can be powered by 110 V AC, or 220V AC, while the scanner motor requires 220V 3 phases(ph). A 440V/3ph transformer was recouped from the old Sperry radar installation, and the original plan was to power the transceivers with 220V/3ph.

After testing, it was discovered that the output voltage of the transformer is too high and cannot be used to power the transceivers. However, the scanner motor is less voltage-sensitive and therefore it can use the power from the transformer. A second transformer (220V to 117V) was connected to the output of the first transformer to power the transceivers, while the 220V was routed to the scanner motor through the transceiver power relay.

6.3 Display Installation

The installation of the display was straight forward and was completed without problems. During discussions with Sperry, in preparation for the installation, the possibility of implementing the original radar system design was considered. The conclusion was reached that the implementation costs would be too high, and insufficient time was available. It was decided to install controls for the HV channels near the display to facilitate transfer from one signal source to the other. This description of the set up was interpreted by Sperry as being a "one or the other" system, whereas our requirement is to have both signals available at all times. Consequently, a special card that

performs the task of switching to either source was delivered with the system and subsequently was returned to Sperry. Local controls were implemented with locally acquired components and installed on the side of the display unit. Figure 9 shows the HV control unit comprising the tuning control, the STC control, the gain control, the tuning indicator, and the selection switch.

Figure 9: Display and HV Tranceiver Control Panel

6.4 General Installation

Where possible, all radar and antenna azimuth signals were routed through the bulkhead area near the three X-Band transceivers. This will allow easy modifications and maintenance in the future. All video and trigger signals were routed through a junction box called the central junction box. It contains a power supply to drive the synchro reference driver, and can

leading to the RDS in the SINSS console, originate from the central junction box. From the RDS, cables carry signals to the port wing Raytheon PPI display. A control box was bulkhead mounted behind the Raytheon display to let the user remotely select the radar source for the display.

7. Conclusions

The system implemented onboard the M.V. Arctic represents the best combination of elements to achieve the goals of this project. The elements of the system are commercially available at relatively low cost. The new system provides the basis for future developments as well as responds to immediate operational needs. The fact that the vessel is now equipped with three independent radars, allows one of them at any one time to operate at different settings or performance levels than the ones stipulated by regulations. This flexibility will facilitate research projects that could not be undertaken on other vessels.

Prototypes of cross-polarized antennas tested to date, were constructed using two array antennas of different polarizations mounted on top of each other. The antennas were difficult to align and the performance of the system was degraded. The high standards of fabrication of the CHL antenna combined with the monolithic construction and the high power levels generated by the Sperry transceivers, guaranty the maximum strength vertical polarized signals possible.

The implemented system is easy to modify and the signals are readily accessible for special applications. The RDS provides a high degree of accessibility to the different radar signals generated on the bridge and constitutes a convenient signal access port.

8. Testing Recommendations

The new radar system will be used for ice navigation, standard navigation, hazardous ice detection, and general marine radar research. Even though the characteristics of each individual component are fairly well documented, the performance resulting from the combination of these components is not known. A number of tests should be made in order to fully characterise the system. This characterisation is necessary to quantify the results of future research projects, and set a reference point to monitor the system's performance. The tests should aim at two objectives:

- Quantify the system's performance as a stand alone unit by measuring such parameters as noise figure, bandwidth etc.

- Collect information to quantify the advantages of the new system in ice, over the X-Band system traditionally used onboard the vessel

8.1 Display Efficiency

The new system comprises a daylight raster scan display that has not been proven to be adequate for ice navigation. Indications are that some difficulties will be experienced in operating the unit in full daylight, because of screen glare and limited display brightness. The study of the adequacy of this display does not justify a dedicated program in itself, but could be an element of a larger project.

8.2 Range Performance

Testing the range performance of the new radar is one of the obvious tasks. These tests are difficult to make by simply measuring return signal from distant non-characterised targets. It is therefore recommended that a series of recorded video images is statistically analyzed to characterise the radar range performance. The images would be recorded in different environmental conditions, at different locations, and different radar settings. Statistics of related data sets could then be analyzed to obtain comparative performance figures. These tests would require the recording of unprocessed video signals, to the full bandwidth offered by the recorded signals.

8.3 Specification Measurements

The characteristics of each component and of the system as a whole should be measured. The relative performance of the different radar systems cannot be characterised without knowing the location and the extent of performance loss. Each component should be tested for bandwidth, noise figure, attenuation etc.. These tests would require the use of specialized equipment rented for the duration of the trials.

8.4 Azimuth Measurement Accuracy

The useful range of the radar system for ice surface mapping, is limited by two factors:

- The grazing angle of the radio waves from the antenna
- The resolution loss associated with the antenna beam width

Increased range and resolution is desirable because it increases the area over which the radar image can be correlated to the SAR imagery during ice navigation.

One of the ways envisioned to increase far range resolution (6 Nm and beyond), is to mathematically process echoes from very closely separated radials. In theory, the resolution could be significantly increased by this process. The success of this method depends on accurate antenna angle azimuth measurements. In the new system, the presence of related pulse and synchro azimuth signals could, after processing, yield the desired accuracy.

A test should be made to characterise the stability and precision with which the antenna azimuth can be measured, and algorithms developed to use the combined signals for that purpose. Closely separated radials could then be sampled and the theory tested.

8.5 Mutual Interference Tests

The introduction of a second X-Band radar on board the M.V. Arctic, addresses certain needs, but also creates some problems. The two radars are usually operated simultaneously. Their proximity, and the small difference in operating frequencies, make them susceptible to mutual interference. For the purpose of normal navigation, the display video processors are generally sophisticated enough to handle the interference. However, for the purpose of ice navigation, such processing is not adequate and an unprocessed radar video signal is generally desired.

Different methods of synchronizing the two radars should be investigated, and methods found to eliminate mutual interference. This may include an arrangement by which each radar is fired in turn while the other's video circuit is blanked. Several methods could be implemented and tested.

8.6 Ghost Image Interference

Radar signals are electronically plotted on the radar display, starting at the moment the transmitter is fired. While the electron beam is sweeping the display screen, any signal received through the antenna and receiver will be plotted regardless of the signal's origin (one reason why different radars can interfere with each other).

For short range operation, commercial radars usually operate at a higher Pulse Repetition Frequency (PRF). The higher frequencies are required to raise the average power level reduced by the short transmitted pulse widths used at short ranges. The use of high PRFs however, creates ghost image problems. A ghost image is produced when target echoes from the last transmission reach the radar antenna after a new pulse has been fired. The ideal situation would be to wait until all possible echoes have been received before firing the transmitter. If the maximum radar system range is taken to be 96 nautical miles, the corresponding minimum waiting delay would be 96 x 12.35 uS= 1.186 mS. This delay corresponds to a maximum PRF of 1/1.186mS= 843 KHz. This maximum PRF is clearly exceeded in most cases when operating on short ranges. The radar manufacturers circumvent the ghost image problem by slightly varying the PRF frequency which changes the relative position of the ghost echoes. These ghost echoes are then eliminated by the display video processor using a pulse to pulse averaging technique.

Pulse to pulse averaging may not be desirable for ice navigation and may in fact be detrimental to high resolution. Section 8.4 discusses high density radial concentration for improved resolution. These high radial densities can be obtained either by increasing the PRF or reducing the antenna rotation speed. At very short pulses (such as those used at short range settings), consistent with the high resolution required for ice surface mapping, the ghost image problem may be less significant because of reduced transmitted power and therefore received echoes.

A study should be made to characterise the extent to which ghost echoes are a problem in unprocessed radar images. Alternate video processing methods should be studied to yield ghost free images while retaining maximum resolution. It may be that the best method would be to reduce the PRF and the antenna turning rate. This may be acceptable given the relatively stable environment while navigating in ice.

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APPENDIX A

Design Constraints

Constraints definition

1.1 Operational constraints
- A) Performance
- B) Clutter Controls
- C) Interference
- D) Functionality
- E) Radar Maintenance

1.2 Physical constraints
- A) Basic Configuration/Controls
- B) Daylight Display
- C) Layout

1.3 Construction constraints
- A) PC boards
  - Board area;
  - Mechanical resonant frequency;
  - Number of layers;
  - Copper thickness;
  - Substrate material;
  - Protective coating;
  - Operating temperature;
  - Component fastening;
  - Board complexity;
  - Trace width;
  - Solder pad size;
  - Mounting configuration;
  - Board markings;
- B) Power supply:
  - Power requirements;
  - AC supply variation tolerance;
  - Number of required voltages;
  - Protection scheme;
  - Regulation technology;
  - Heat generated;
- C) General construction:
  - Modularism;
  - Component accessibility;
  - Interconnection methods;
  - Cable quality;
  - General identification and markings;
  - RF shielding;
  - Switch quality;
  - Display beam rotation technology;
  - Ease of disassembly;

D) Circuitry:
Level of integration;
Function separation;
Over-design factor;
Drive capacity;
Component choice;
Test point provision;
Test mode provision;
Level of customization;
Number of adjustment points;
Compensation provisions;
Parts rationalization;
Adjustability;
Component dependence;
Radar signal demodulation;

E) Miscellaneous:
Documentation adequacy;
Availability of parts;
Cost;
Customer support;

1.4 Research Constraints

Access to most functional block entry and exit points;
High degree of modularism;
Standard operating parameters;
Moderate level of integration;
Possibility to vary antenna rotating speed;
Independence of raw video from display controls;
Full documentation;
Adequate output buffering;
Wide tuning range;

1.5 Regulatory constraints

A) Governing rules
B) Performance specifications
C) Operation

1.1. Constraints definition

1.1.1. Operational constraints

The operational requirements associated with the use of a radar system on an Arctic going vessel, are distributed in three areas. These areas correspond to distinct but related functions of the radar equipment on these ships; open water navigation (normal navigation), iceberg infested water navigation, and ice navigation proper.

Open water navigation requires long range detection of weak or cluttered targets, with a reasonable degree of range and bearing accuracy.

Iceberg infested water navigation is similar to open water, except for cross polarized techniques that are used to differentiate between soft ice and hazardous old ice types, as found in open or semi infested water environments.

Ice navigation is primarily concerned with the correlation of radar image features, with similar features identifiable in the SAR imagery. This last function is radically different from the previous ones and requires different system and display characteristics.

In order to define the radar operational requirements for ice navigation, a number of subjective and technical areas must be addressed. The question of what specific characteristics produce a good radar picture in ice is central to this definition.

At this time, our experience is based on current shipboard equipment and our subjective assessments of what is best for an ice radar is arrived at without access to field experience in ice, with the most up to date and technically advanced radar systems.
On board the M.V. Arctic, a number of radar systems have been used. Of these systems, one has retained attention for work in ice; the Decca X-band model AC 1629C which features are summarized in table 1.

TABLE 1

X-Band, 3 cm wavelength
Logarithmic Receiver
25 Kw output
9 foot Antenna
16 inch display screen (Dark Display)

Range (Nm)	Pulse Length (uS)	
	Short	Long
.25	.05	-
.50	.05	0.25
.75	.05	0.25
1.5	.05	0.25
3.0	.25	1.0
6.0	.25	1.0

Pulse Length (uS)	PRF (Hz.)
.05	3400
.25	1700
1.00	850

This radar produces the best picture in ice with very little if any clutter control applied. Adjusting the gain and sea clutter is usually all that is needed. For comparison, the above radar is considered the most useful of the on board systems. It produces good definition of ice features in pack ice, large floes or continuous ice covers.

It is hoped that by identifying the characteristics and performance we know to be important in our current radar equipment, an informed appraisal can be made of new radar systems and their suitability for ice navigation.

A) Performance

The requirements for an ice navigation radar are unique and considerably different than those for normal navigation. The differences are mainly focused on useful range, and display aspect. The ice radar is primarily a short range aid, being useful to a maximum of approximately six miles. The display must render a very detailed picture of what would normally be considered unwanted clutter. Within the range that ice can be detected, all available returns must be displayed on the radar screen. This enables the navigator to interpret the information, searching for ice types, features, and open water leads.

This function requires high sensitivity, excellent range and bearing discrimination, short pulse lengths and a display screen capable of accurately showing the fine details present in the returned echoes. The radar must clearly show subtle variations in ice topography as found in ice floes, pack ice, as well as larger ice features such as

ridges, bergy bits (1) and icebergs. Any returns that supply useful information of the surrounding ice cover must be displayed, unaltered, on the viewing screen.

Some of these features are difficult to detect due to the rounded shape and low freeboard of the ice. Detecting small, old or glacial ice targets buried in ice floes, is of paramount concern to the navigator because of potential ship damage.

Conversely, normal navigation benefits from long range target detection, sea, rain, and ice clutter elimination, resulting in the enhancement of weak target echoes. Very often, extensive signal processing is performed by the machine, in order to render the kind of display that is required for this application.

(1) Bergy bit: House size piece of glacial ice.

B) Clutter Controls

Opposite to normal navigation, where targets are highlighted and sea, rain, and ice clutter are defeated, ice navigation requires that all clutter reduction functions be reduced to a minimum. Any distortion introduced by signal processing such as echo enhancement, brilliance levelling or echo stretching, will severely impair the radar's usefulness. For ice navigation, the background clutter is required to properly identify the ice type or ice feature being detected. The radar system must allow to turn off all forms of video processing and automatic clutter reduction functions.

For example, the Decca radar system on board the M/V Arctic is equipped with a clear scan video processor system that essentially performs echo thresholding and scan to scan re-enforcement. This system, called VP1/2, can be switched in or out of circuit as required. Thresholding transforms very weak target echoes into full brilliance targets on the screen, while scan to scan re-enforcement attempts to eliminate false echoes. While this system is usually very useful for standard navigation, it has been found to be inadequate for ice navigation in general. The picture produced while video processor 2 (VP2) is activated, is distorted, lacks contrast (effects of thresholding) and does not permit the identification of useful features in the image. This processor has therefore been disabled during ice navigation.

C) Interference

The new radar will comprise two independent but related data channels, that will be used simultaneously while navigating in ice. Furthermore, the other radar system on board the ship will be used at the same time for other tasks or functions. Since the two radars operate in the same frequency band, inevitable interference will occur. Many techniques exist to eliminate this problem, some more successful than others. Probably the easiest to implement is transmitter synchronisation, implemented by triggering one transmitter with the transmit pulses from the other. Another technique, is to process the video signal to eliminate what is believed to be false echoes. Which ever technique is implemented, the chosen radar should have the capability to eliminate this interference.

D) Functionality

As mentioned before, radar frequency bands have been chosen for each specific application. X-Band frequencies have been recognised as the most usefull for ice navigation, while S-Band radar is best in heavily cluttered environments. X-Band radar frequencies, three times shorter than S-Band, will interact more strongly with potential targets, and will "see" smaller features than is possible with S-Band. This also implies however, that X-Band radar will pick up more clutter than S-Band will at any given time. Even advanced clutter reducing processing will not permit an X-Band radar to render the same clutter free display that an S-Band radar will produce. For this reason, an S-Band radar is more usefull than its X-Band counterpart, in detecting large features such as coastlines and ships, in a heavily cluttered environment.

In essence, it can be said that for Arctic navigation, the availability of an X-Band radar is essential, and that adequate backup must be available in case of failure of the main radar unit. An S-Band radar cannot be used as an ice navigation tool, and cannot be considered a suitable backup unit in case of failure of the main X-Band unit.

Of more recent origin is the cross polarized techniques for detecting hazardous ice conditions. It has been found that old ice (more than a year), will scatter incident radio waves and return echoes of multiple polarization. This property of old ice is not shared with level first year ice, but is found partialy in heavily ridged first year ice. These two ice types are considered hazardous to navigation and should normaly be avoided.

Therefore, a radar equiped to detect exclusively verticaly polarized signals will pick up echoes of hazardous ice conditions only. The Christiaan Huygens dual polarized antenna purchased by Canarctic, will be used for such a purpose. The information contained in the vertical polarized channel will help the navigator to avoid hazardous ice conditions. The usefulness of such a system will be most prevalent in the fall, for detecting old ice in a matrix of first year ice. In this situation, cross polarized techniques are the only ones capable of providing some degree of warning. The usefulness of the system will be enhanced by making the vertical polarized channel available on at least one radar display on each side of the bridge.

Interswitching will improve the redundancy and reliability of a system if it can be implemented. The benefits of interswitching have to be weighted by the cost of implementation. Interswitching can be implemented at the display level, the transceiver level, or at the supply level. Previous discussions provide sufficient justification for the implementation of interswitching at the display level, and this will probably be included in the new system to some degree.

Interconnection at the transceiver level is more complicated and may not be possible for some combinations of displays and transceivers. Depending on the chosen radar system, it may be that interswitching will be readily possible and should be implemented. Given the number of radar systems to be implemented on the bridge of the M.V. Arctic, it is likely that this feature will not be needed. Reevaluation of this requirement should be made, once the radar system has been chosen.

Interswitching at the supply level, will be required for systems that are connected to some form of power converter such as a motor generator or an electronic inverter. Again, compatibility between the different systems is the issue and should be the prime decision factor. Systems connected directly to power panels without the use of a power converter, will not need interswitching. Direcly connected radar systems, are usualy connected to an emergency power supply which is inherently redundant and thus do not require additonal forms of interconnections for redundancy purposes.

E) Radar Maintenance

The radar display unit should be designed for simple routine maintenance and cleaning. Radar displays are prone to dust collecting and the display control area should be designed and built to promote easy access and cleaning. Sharp recess and angles should be avoided. Textured surfaces have a tendency to collect dirt and are generally very difficult to maintain. All control knobs and switches should be designed to be easily removed for cleaning when required. The controls and display area should be made of a material that is not damaged by usual household cleaners. This specifically applies to control labelling.

Such items as fuses and jumper settings, should be easily accessible if required. Very often, a system fault can be rectified by replacing a fuse. In situations where time is a critical factor, easy access to the control fuses can be significant.

In general, clear and comprehensive documentation is as much a part of a radar system as any of the components. Consistency and error free literature about the system is essential and should be supplied

at the time of purchase. The documentation should include service manuals for each individual component, and installation manuals complemented by the particulars of the ship's installation. Most important, a clearly laid out complete operations manual, including examples and a basic troubleshooting guide.

1.1.2 Physical constraints

A) Basic Configuration/Controls

The requirements in ice are such that the navigator must frequently move around the bridge for different views of the ice ahead and astern, to look at different radar displays and to control the movements of the vessel. The operator often has to repeat these operations at regular intervals of short duration. Given the number of tasks he has to perform in a relatively short time, and the occasional urgency of some tasks, no time can be wasted trying to find the controls on a radar display. The radar controls must be situated on the three sides of the screen most easily available when standing behind the display, and arranged for ease of operation while in that position.

All basic controls must be operable without the necessity for the operator's attention to deviate from the display. This has been facilitated in the past by using knobs of different sizes and shapes to help distinguish between, and locate controls by touch. Some simple and sensible control arrangement is required. All radars manufacturers tackle this problem differently and they generally all produce good arrangements. The value of each is more a matter of personal preference than a question for objective evaluation.

Currently, three types of controls are popular; rotating knobs, push buttons and touch pads. Personal preference is again the key to what is "best", but all of the navigators agree, until proven otherwise, that the following basic controls should be of the rotating knob type:

- Gain Control
- Tube Brilliance
- Rain Clutter
- Sea Clutter
- VRM (Variable Range Marker)
- EBL (Electronic Bearing Line)
- Panel Light Brilliance
- Plotter Light Brilliance
- On/Off Switch

The button or touch pad type of controls generally require that operator's attention be shifted away from the display picture, to locate and operate them. Rotating knob controls are easily located and operated by touch, without the need for visual contact. On a bright daylight display, this may not be as much of a problem, as the operator can easily shift his attention to and from a control positioned close to the screen. This can be done without the inconvenience of changing light conditions as on a conventional PPI display. For this reason, the choices and types of controls used on a daylight display radar, are less restricted than on a conventional radar display.

Lastly, all controls and markings must comply with the IMO standards which are clearly outlined in the regulations manuals. Most radar system manufacturers usually comply with these requirements and in practice, this is never an issue.

B) Daylight Display

In arctic conditions of twenty-four hour daylight, the sun is low on the horizon, often in the navigators eyes and always creating a bright operating environment. Eye strain is common when a conventional dark radar display is used in these conditions, and the operator is forced to change back and forth between the dark radar and a bright environment. This situation is worsened by fog, which creates an even brighter environment.

For this reason, it is believed a bright daylight display would be more appropriate for an ice radar. Such a display would remove the strain and time delay associated with using a dark display in bright surrounding light conditions.

It is of concern that the daylight display, employing raster scan technology, renders as good a picture as the one produced by the presently used conventional radar display. Fine details can only be reproduced by a high definition screen, with the information updated at a high rate. Experiments on board the M/V Arctic have been inconclusive with regards to the adequacy of such displays, because of the low quality of the units evaluated. Newer units are now available with high definition displays that render an image very similar to the ones produced by a conventional PPI display, with the addition of graphics and colour. However, consulted navigators,

Captains and ice pilots, are unanimous that colour should be avoided in this type of display. The addition of colour to an already complex picture would only confuse the operator and prevent the identification of ice features and other useful elements of the display.

Also of concern, is the glare produced on the surface of the display in daylight conditions. This may severely restrict the usefulness of such displays to the point where they may be unusable. Surface glare is inherent to all displays, and is not a problem in PPI displays because of the use of a shielding hood, without which they would be unusable. The name daylight display was first given to raster displays, because of the much higher brightness achievable with this technology, as compared with the more conventional PPI displays. Surface glare can be reduced by adequately positioning the display surface to avoid light sources in the reflection path. Experimentation can show that the two optimum angles for a standing operator is a vertical or horizontal screen surface. A vertical screen surface is impractical because of the resulting viewing angle, while a horizontal screen surface creates aesthetics and operational problems. It would appear that a partial hood, assisted by a properly textured screen surface, would resolve most problems in this area.

C) Layout

The most adequate layout for a radar system, can be derived from experience, physical constraints such as available space, and operational constraints imposed by the tasks to be performed with the equipment. Additional constraints come from available

electrical supplies, proximity to wave guides, and the need for servicing access.

The operator will benefit the most from the radar display if it is positioned near a window, so that correlation can be made between the radar picture and the immediate environment. Consequently, the radar displays should be positioned facing forward, near windows located at the front of the bridge.

Given the fact that four different radar signal sources will be available on the bridge of the M.V. Arctic, care should be taken to provide access to these signals to displays distributed evenly on both sides of the bridge. This can be done by providing access to multiple signal sources to each display, or by increasing the number of displays. It is important for ice navigation for example, that the cross polarized HV signal be displayed simultaneously with the standard HH signal on a different display. The HH display is then used for standard navigation, while the HV display is used for close range hazardous ice detection.

1.1.3 Construction constraints

A) PC boards
Thickness;
In order to resist heavy vibrations, and generally tolerate mechanical abuse, it is advisable that the printed circuit boards be constructed from heavy gauge base material.

Board area;
The board area is affected by many variables and will be a compromise between often conflicting requirements. One must consider the need to group certain functions together, while promoting modularism. The conductor width and spacing have a direct bearing on board area, although the use of double sided technology will reduce this impact considerably. The choice of components also affects the area, unless larger components are externally mounted. The component mounting method can reduce the board area, but at the expense of sometimes reduced mechanical integrity or serviceability.

From a construction point of view, the denser a board becomes, the more delicate and expensive it becomes to repair. The desirable compromise will promote; serviceability, mechanical integrity by increased stiffness and sufficient component mounting and operating area, reasonable modularism by careful planning of the functions implemented on the board, and accessibility by allowing easy dismantling.

Mechanical resonant frequency;
The PC boards must be of sufficient thickness or fastened adequately so that the natural resonant frequencies fall out of the range of those encountered on the bridge of a typical ice breaker. Adequate fastening to the chassis must be provided on the board, in the vicinity of heavy board mounted components.

If support cannot be adequately provided on the board, the heavy components should be externally mounted to relieve the strain.

Number of layers;
In order to promote serviceability, the number of conductor layers should be restricted to two. The addition of a third layer would prevent any repairs to the centre layer. Furthermore, internal layers make diagnostics more difficult and increase fabrication costs unless the units are mass produced.

Copper thickness;
The highest copper thickness available for the PC board grade material should be used. The extra thickness provides better current carrying capacity plus improved mechanical integrity. The added thickness also promotes better heat distribution and will sustain a higher current short circuit.

Substrate material;
Only moisture resistant, multilayer fibre-glass base material should be used. This provide increased toughness and dimensional stability under thermal cycling. These requirements may change in the RF section of the transceiver, where micro-stripline design techniques can be used. In that particular case, the preferred base material is teflon with it's low dielectric loss factor and it's isotropic properties.

Protective coating;
The marine environment often exhibits humidity levels beyond what is normally encountered in normal shore based installations. The salt content of water droplets floating in air, cause a significant

problem in corrosion control and surface dust layer conductivity. The accepted solution to this problem is to have the finished and tested boards covered with a protective coating. This coating, called conformal coating, effectively seals the board and components, protecting them from corrosion or contamination. The coating also adds mechanical integrity by effectively gluing parts to the board, thus reducing vibrations.

If repairs have to be effected, special solvents can be used to dissolve the coating and gain access to bare metal or remove parts. The prospective radar should be protected in this way or an equivalent system.

Operating temperature;
The more condensed a board becomes, the more heat has to be evacuated from the board and the operating temperature rises. In most cases, even though the heat can be effectively evacuated, the operating temperature will eventually (within two to three years), reticulise the polymers in the fibre-glass base material, making it brittle and giving it a burned appearance. Care must be taken not to exceed the critical temperature for the base material even if that temperature is well within the operating limits of the component generating the heat. Proper heat sinking should be provided, or the offending component should be mounted away from the board surface. Ventilation should help in alleviating these problems, as long as dust contamination is dealt with. The preference is clearly towards sealed enclosures to prevent dust and humidity contamination.

Component fastening;
Components mounted on the boards should be fastened in a way that promotes easy access and repair, while maintaining mechanical integrity. The use of rivets for component fastening is not considered an acceptable alternative because of reparability problems. Moderately heavy components such as electrolytic capacitors, should be provided with extra fastening other than lead soldering to the PC board.

Board complexity;
In order to promote serviceability, board complexity should be kept within reasonable limits. Extreme limits would be to have all the circuitry concentrated on two boards, or have a circuit board for every amplifier stage for example. Most radar manufacturers will separate boards according to function or stage, for example; front end, IF stage, video preprocessor, video amplifier etc.

However, new technologies such as surface mounting, would allow extreme integration, concentrating the complete RF and IF circuits on one board, half the size of a present IF board on a typical radar. This may be desirable in the case of the high frequency circuits, as long as spare modules are easily available at reasonable cost, and are easy to replace with minimal or no adjustments. Accessibility of internal signals may become an issue from the trouble shooting point of view or for R/D purposes, in which case it may be desirable to keep integration to a medium level, a limit of which will be dictated by other considerations and common sense. With the present day technology, it would be possible

to fit a complete radar circuitry into a box the size of a personal computer. The question is whether or not this is desirable.

Trace width;
Copper trace width should be heavier than the normal industry requirements. Many times, shipboard technicians have no choice but to effect component replacement on the run, with limited repair equipment, under less than adequate working conditions. This can result in damaged conductor traces and burned components. If the traces are wider than the minimum requirements, chances of damage are reduced by as much. Wider traces also facilitate repair because of the added solder surfaces and heat dissipation capacity.

Solder pad size;
The same rules applying to the trace width also apply to the solder pad size. Even though the standard size will do nicely for standard applications, an increased solder area for component leads will be beneficial. This also insures that trace to base material bonding will not suffer during repair. Naturally, an upper limit is imposed by lead spacing and board area. In order to keep pad size to a maximum, the least amount of IC inter-lead traces should be used with most of the routing done around ICs. One exception to this rule would be on computer boards, used to control display or perform functions such as ARPA.

These boards usually far exceed the complexity of analog boards in terms of signal interdependency, making diagnostics very difficult and requiring sophisticated test equipment not generally found on a ship. The only alternative for these boards is then to have a replacement on the ship and the board should include some form of self test function that can assist in troubleshooting in case of failure. These considerations reverse the earlier requirements for PC boards, since their complexity prevent anything useful from being done on board the ship. The requirements for these boards would then be maximum complexity and minimum board size. However, all other functions should be kept separate from this board, reserved for non-diagnosable digital computer functions.

Mounting configuration;
The boards should be mounted in a way that promotes access and removal while maintaining the other requirements. Boards should be accessible without having to disassemble half of the radar display to reach it. Adjustments and test points should be accessible without having to lean on the high voltage power supply to do so for example. In that sense, the component placement and orientation on the board should be carefully planned, as well as the final board mounting position in the enclosure.

Board markings;
It is paramount that the overall markings throughout the unit be explicit, clear, permanent, unambiguous, consistent and visible. The success of trouble shooting, part identification, general maintenance, depend on the fact that all components and parts of the

radar be easily identifiable. Component identification on the board, should be readily visible and not covered by the components themselves, to the extent that board area and component placement do not significantly suffer from it. Where clear identification is not possible (this should be rare), documentation should adequately supplement the lack of clarity. Cable harness and circuit board no. should be clearly visible and marked in a permanent way.

B) Power supply:

Power requirements;

To allow maximum flexibility during installation, the power supply should include the options for multiple supply voltage choice. The actual power requirements (current demand) should be within reasonable limits. One can think of a radar where the antenna would be driven by a DC motor who's current would be supplied by the radar's internal supply. This would boost the power requirements for the radar, beyond what would be expected of a modern state of the art radar. In that sense, unnecessary voltage regulation brought about by unorthodox circuit configuration should be avoided.

AC supply variation tolerance;

It is a well known fact that power fluctuation is a hallmark of the shipboard environment. The power supply should be designed to be highly tolerant of AC line variations. The circuitry should be able to withstand repeated power surges and on/off cycles in a relatively short time, without suffering any damage or performance degradation.

Number of required voltages;
The circuitry should be such, that it does not require an unreasonable number of different voltages. A maximum reasonable number would be around 5 different ratings. These would be for example, + 5 volts, +/- 12 to 15 volts, 300 to 400 volts and 2500 volts for CRT drive purposes. Preference would be given to reduced requirements in terms of number. A reduction in requirements can be achieved by providing local voltage regulation from a higher general distribution voltage.

Protection scheme;
In order to fend against regulator failure or overcurrent events resulting from short circuit or component failure, adequate protection should be provided in the power supply itself. A number of techniques are available for protection, ranging from simple fuses to current limiting and foldback regulator characteristics.

The supply should certainly provide protection against overvoltage and overcurrent. The preferred choice will be for designs that do not require fuse replacement and provide some means of determining the cause of failure when it occurs. For example, some indication should be provided to the user, when overvoltage has occurred or when a short circuit is present at the output of the regulator.

Regulation technology;
High efficiency, compact and reliable technology will be favoured. The use of switching technology will be sought, complemented by linear final regulation stage if required. The efficiency and

tolerance of this technology, makes it a good choice where applicable. Increased efficiency also means reduced heat dissipation and power consumption. Switching technology generally provides more compact power supplies with increased reliability.

Heat generated;
As mentioned earlier, heat dissipation is an issue, but more so in the power supply, where the circuit function inherently promotes heat generation. In itself, this is not a problem if the heat is adequately dissipated. However, the less heat is generated, the less has to be dissipated, and the more the enclosure is likely to be hermetically closed without temperature problems. Here again, efficiency and compactness will be favoured, thus a strong bias towards switching supplies.

C) General construction:
Modularism;
The breakdown of the circuitry in functional modules is highly desirable. This breakdown must be made schematically as well as physically to yield the highest benefits. Modularism allows faster troubleshooting, easy replacement, lower repair cost and the possibility to upgrade the circuitry when newer board versions are produced. Modularism also allows a wider margin in general layout and concentrates shielding where it is needed. The high voltages are restricted to where they are used and RF circuitry can be kept separate from other parts of the system.

Modules should be defined with the goal of isolating a particular function and minimizing the interconnections.

Component accessibility;
All replaceable items should be kept as accessible as possible. All circuitry should be concentrated in the fewest compartments possible. The situation whereby all components must be removed in order to reach another one, is highly undesirable and should be avoided. Compartments should be closed using conventional fasteners in reasonable quantity. The use of special fasteners requiring special tools should be avoided in all parts of the system.

Interconnection methods;
Modularism implies that modules will have to be interconnected to allow signals and power to flow in and out of the cards. The use of conventional low cost connectors should be avoided. Where possible, the use of DIN connectors should be encouraged. High frequency signals should be connected using adequate connectors such as BNC. As much as possible, edge card connectors should be avoided. Insulation displacement connectors should be restricted to low current applications such as ribbon cable carrying digital data.

Cable quality;
Only the highest quality wires and cables should be used in the construction of the unit. All wiring calculations should include a

substantial security factor to allow for possible future modifications or changes in the service profile.

General identification and markings;
The same rules apply here as in the circuit board marking requirements. In addition, a numbering system as opposed to a colour code will be favoured. Experience has shown that some colours will change with time, dirt and other contaminants will alter the appearance, changes in cable suppliers during manufacturing result in differences in the colour codes referred to in the service manual. Colour blind personnel will be impaired by a colour code. If part of the wiring has to be changed subsequent to damage, it may be impossible to find the same colour code wiring.

One exception to this requirement, is for ribbon connectors, where individual conductors can be identified by rank. All markings should be consistent with the supplied documentation and the logic behind the identification system should be clearly outlined.

RF shielding;
Parts of the circuit sensitive to or emitting radio frequencies or magnetic radiation, should be adequately shielded with easily removable and replaceable material. High voltage systems should be adequately protected and insulated to prevent injuries to users.

Switch quality;
Switches being a critical part of the system, only the best quality sealed units should be used in the construction of the unit.

Switches are a source of intermittent or otherwise undefined problems that can be difficult to locate and repair. The use of high quality material will reduce the chances of such an occurrence.

Display beam rotation technology;
The CRT trace rotation should be performed electronically. Motors and gears coupled to the deflexion coils should be avoided. A mechanical system is subject to ware and back-lash, requires extra maintenance, has considerable inertia which may in some cases introduce tracking error, and has reduced reliability because of the inherent slip rings. Instead, the more reliable electronic rotation technology should be used.

Ease of disassembly;
The unit should be built in a way that permits easy and safe access to all components. The number of fasteners should be reduced to a minimum without sacrificing mechanical integrity. Most components should be individually accessible, without having to dismantle any other part except the access panel.

D) Circuitry:
Level of integration;
The circuit function should dictate the level of integration. It is acceptable to have high levels of integration in parts of the circuit that are difficult to service and that require special test equipment do so. Chances are, that these circuits could not be

serviced on board the ship, regardless, because of the lack of suitable facilities and test equipment. One example of this, would be the IF strip of the receiver, or special high frequency circuit as in coherent radar. One other part of the circuit with similar attributes, would be highly complex computer systems such as in ARPA radars. All other parts of the circuits, should be designed using relatively standard technology that is easily available in most ports.

Function separation;
It is desirable to have circuitry that clearly separates functions, to promote serviceability and reduce function interdependence. It is possible to design circuits that integrate multiple purposes. For example, an oscillator could incorporate a load sensing and feedback loop, a waveform shaping addition, as well as different outputs used in various parts of the system. While such design promotes low fabrication cost (this is merely an example), it also increases the interdependency of the functions. When a problem occurs, it becomes very difficult to trouble shoot the problem. In a typical case, circuit A will use the output of circuit B as an input, but circuit B uses part of the signal generated by circuit A such that some external signal source will have to be used in order to get at least circuit A or B to operate so that servicing can be undertaken. Multiple level feedback loops should be avoided, as they exhibit the same problems. Circuit design with clearly separated and implemented functions will be favoured.

Over-design factor;
Survivability of a system is a question of the amount of over-design built in the system, as well as inter-stage isolation. There is however a limit to the separation that can be implemented in the system and survivability then depends on the over-design factor. Where susceptibility is great, such as inputs or outputs, ample reserve capacity should be allowed for.

In general, components should be used at no more than 75% of the rated maximum parameters.

Drive capacity;
The radar, being used as a master for an undetermined number of slaves, will have to have sufficient drive capacity built in the outputs to supply the demand. A reasonable figure would be to have at least triple the drive capacity of a normal load for the selected radar system. This requirement is closely related to the over-design factor, and a system designed with sufficient tolerance should easily comply.

Component choice;
Exotic components, having characteristics that are critical for circuit operation, with restricted tolerance should be avoided. For example, special transistors versions of popular units, with extended voltage or power capacity, should not be used in replacement of a unit having inherently more capacity that would be more tolerant. Special components, available from a single source only, should be avoided.

Test point provision;
Strategically located test points, should be included in the design of the unit, and these test points should be easily accessible with the circuits in position. These test points should be located in parts of the circuit where measurement instruments of normal characteristics will not significantly affect the circuit operation. Where needed, the test points should be routed through isolation resistors or otherwise restricting components.

Test mode provision;
The system should allow special operating modes, specifically aimed at trouble shooting. Typically, the test mode will permit to isolate part of the circuit and perform individual function testing.

Level of customization;
Except in specialized parts of the circuits, customization by the manufacturer is not a desirable feature.

As pointed out in other requirements, parts availability and exchangeability will be favoured. However, programable devices such as PALS are acceptable. To a certain level, ASICS could be considered, provided that adequate documentation is provided and a suitable quantity of spares is delivered with the unit or sourcing is guaranteed.

Number of adjustment points;
Since adjustments often require special test equipment and controlled operating conditions, the number of adjustments should be kept to a minimum. Automatic biasing and circuits such as AFC and AGC will be strongly favoured. In circuit references and precision resistors as well as component arrays, should help to reduce the number of necessary adjustments. The necessary adjustments should be easily performed with minimal test equipment. Test modes should be provided to assist when adjustments are critical.
Compensation provisions;
Where needed, compensation should be provided to reduce the effects of temperature or voltage variations on operating parameters.

Parts rationalization;
In order to reduce the amount of different spare parts required, special effort should be put into rationalizing the choice of parts in the design. A typical example would be to use 6 different transistors in an amplifier design, where 3 would have done nicely. This design philosophy produces circuits with inherent over-design in some cases, but it also reduces the parts diversity and reduces device dependency.

Adjustability;
Where adjustments are provided, circuit design should be such that adjustments are relatively easy to make. The full adjustment device travel should correspond to a reasonable range of the controlled variable. Adjustments are often too tight, with slight movements of

the control corresponding to very large variations of the controlled variable.

This is not desirable and if large variations of the adjustment are required, dual controls should be provided; one for coarse adjustments and one for fine adjustments. Tight controls are also inherently unstable since very slight movements of the control take the circuit out of adjustments. Multi-turn controls are an acceptable alternative, provided the best quality devices are used.

Component dependence;
Circuit design should be such that operating parameters are minimally dependant on device characteristics, this excludes reference devices for which the opposite is true. Extra stages should be used in order to reduce device dependency.

Radar signal demodulation;
For the purpose of the dual role of this radar system, and the varied requirements imposed on the video signal, it is preferable to have a logarithmic IF processor. In addition, gain control should be done after the primary video output, so that the signal is not affected by adjustments on the master station. In that way, all slave displays will benefit from independent operation, in accordance to the purpose of each station.

E) Miscellaneous:

Documentation adequacy;

Full documentation should be supplied with the system. This includes:

- Full circuit schematic
- Wiring diagram
- Printed circuit board layout
- Replacement part list
- Full service instructions with typical voltages and waveforms
- Device characteristics
- Circuit description, with design and operation theory
- Full operating instructions
- All mechanical drawings
- Installation instructions
- Factory acceptance tests report

All schematics and drawings should be clearly readable, drawn at a suitable scale for circuit reading. Schematics should be laid out in a way that promotes function understanding with suitable comments and identification on the schematics.

Availability of parts;

Availability of parts worldwide is considered a critical issue, and system design should reflect this concern. Wide international distribution networks of a company can compensate for utilization of special parts but to a limited degree, subject to evaluation.

Cost;
System cost is of considerable importance, and close evaluation of cost/benefit ratio will be undertaken. Cost of replacement parts and service calls will be a major consideration.

Customer support;
The availability and quality of customer support is of primary importance. Technical support for matters outside the normal scope of operation or for special problems should be readily available at reasonable cost and of high quality.

1.1.4 Research Constraints:
Access to most functional block entry and exit points;
In order to cater to future research needs, most functional block entry and exit points should be available to outside circuits. One example would be access to the IF signal before the IF strip. This implies that the signal is routed to the strip using a connector and coax cable. Also, the signal should be adequately buffered and have a low enough noise figure so that the signal quality would not be significantly affected.
High degree of modularism;
To permit easy modifications or adaptations, a high degree of modularism is desirable. Modules such as; video processor, primary and secondary IF strips, display control interface, STC generator, are examples of the desired modules.

These modules could be physically separated or they could be clearly identifiable on PC boards.

Standard operating parameters;
All operating parameters should be as close as possible to the most widely accepted ones on the market. Video signal should be negative going, having a mean amplitude of 2 volts P/Pk, a bandwidth of 20 Mhz or so and have log format. The synchro signals should be 400Hz reference,three phase and approximately 20 volts peak amplitude. These are examples of standard operating parameters and similar definition apply to all other main parameters.

Moderate level of integration;
In order to facilitate modifications required by future projects, the level of integration should be kept relatively low. This will permit to change or modify parts of the system that would otherwise be unavailable unless the whole functional block was replaced. Low integration level also permit the replacement of components with more advanced ones for improved performance or different characteristics.

Possibility to vary antenna rotating speed;
As all other parameters, the antenna speed should offer the possibility of direct control. This is usually no problem with DC motors, but they have the disadvantage of requiring substantial maintenance. Three phased motors are the best choice, since modern controllers exist to control voltage and frequency to drive these

motors. These controllers permit the control of speed and torque characteristics of the motor over a wide range with a simple analog voltage input. The only concern would be with the ability of the gear box to accommodate different speeds and torques than the ones experienced at the rated speed.

Independence of raw video from display controls;
Because of the multiple devices that will be connected to the new radar, it is essential that the video signal be independent from the variations imposed by the main display controls.

The logarithmic format of the video signal will ensure that the video signal is always at a relatively constant level. Any variations in the output level will easily be handled by each repeater controls.

Full documentation;
The modifications or connections necessary for future projects, will require full documentation to be supplied with the radar system. This documentation should cover all aspects of construction, circuit functions and theory of operation.

Adequate output buffering;
Most standard signal sources, as available at the output of functional blocks, should be capable of handling the extra load of external connections. The external connections will comply with standard load characteristics (properly terminated etc.).

Wide tuning range;
In order to cater to possible projects dealing with multiple transmit frequencies, the receiver should lend itself to an extended tuning range. This would mean for example that the receiver might have to tune to two different frequencies on alternate pulses. The switching from one frequency to the other being handled by additional circuitry.

1.1.5 Regulatory constraints

The regulations applicable to radar equipment on board a ship such as the M/V Arctic are relatively few but specific in nature. It must be pointed out that the regulations are ship type and size dependant and the present summary is specific to the M/V Arctic. Any extrapolations and transpositions cannot be made, based on the present text, and specific applications require referral to the original regulation documentation, as published by the Canadian Coast Guard and the International Maritime Organisation. These two organisms, essentially set the same rules, and the most stringent of both sets have been presented here.

The following documents may be consulted for further details on regulations applying to radar systems:

- Transport Canada, Coast Guard, TP 3668 E, Standards for Navigation Appliances and Equipment, 1983.

- Transport Canada, Coast Guard, TP 2872 E, Standards for Radio Installations and Related Equipment, 1981.

- The International Maritime Organization Resolution, "A.281(VIII) Recommendation on General Requirements for Electronic Navigational Aids".

- The International Maritime Organization Resolution, "A.477(XII) Performance Standards for Radar".

- The International Maritime Organization Resolution, "A.278(VIII) Supplement on Standards for Navigational Radar Equipment".

- The International Maritime Organization Resolution, "A.422(XI) Performance Standards for Automatic Radar Plotting Aids (ARPA)".

A) Governing rules

These rules determine the type and number of radar to be fitted on the ship.

- Two complete radars, capable of functioning independently of each other, will be fitted on a ship exceeding 10,000 tons. Wherever convenience dictates and to increase redundancy, the two radar systems may be inter-switched, notwithstanding their independency capability.

- Each radar display must be equipped with plotting apparatus. The same plotting equipment can be made common to both displays, with the provision that immediate proximity to the displays be maintained.

- One of the radar displays, will be equipped with an Automatic Radar Plotting Aid. Rules specifying the performance and functions of this particular equipment are extensive and will not be included in this abstract.

B) Performance specifications

- With the antenna mounted at a height of 15 meters, in the absence of clutter, the radar system will give a clear indication of coastlines at 20 nautical miles when the ground rises to 60 meters, at 7 nautical miles when the ground rises to 6 metres. At 7 nautical miles, a ship of 5,000 tons, whatever her aspect, at 3 nautical miles, a small vessel of 10 metres in length, at 2 nautical miles, and object such as a navigational buoy having an effective echoing area of approx. 10 square metres.

- The surface objects described above, will be clearly displayed from a minimum range of 50 metres up to a range of one nautical mile, without changing the setting of controls other than the range selector.

- The display shall, without magnification, provide a relative plan display in the head-up unstabilized mode with an effective diameter of not less than 340 millimetres for the first display and 250 millimetres for subsequent displays.

- The equipment shall provide adequate range scales, with the range scale displayed and the distance between range rings clearly

displayed at all times. The scales shall be one of the following:

.5 to .8 Nm, 1.5, 3, 6, 12, and 24 Nm (nautical miles)_
or
1, 2, 4, 8, 16, and 32 Nm

- A variable electronic range marker shall be provided, with digital range display. The range will be measured with an accuracy of no less than 1.5% of the scale in use, or 70 metres whichever is greater.

- The range rings and variable range marker will be completely removable from the display, and the intensity will be continuously variable.

- The heading shall be indicated on the display by a heading marker line no wider than .5 degrees, with and accuracy of better than plus or minus one degree. The heading marker line must be momentarily removable but cannot remain off once the control is released.

- Provisions will be made to measure quickly the bearing of any echo on the screen. The bearing of an echo at the outer periphery of the screen will be measured with an accuracy of better than one degree either side.

- On a range scale of 2 Nm or less, the display shall be capable of discriminating between two objects at a range of 50% of the

selected range or more, separated by 50 meters on the same azimuth, or separated by no more than 2.5 degrees in azimuth.

- The range performances will not be affected by the ship rolling or pitching more than 10 degrees from vertical.

- The display will be provided with the means to gyro stabilise the picture with an alinement accuracy of better than .5 degrees at a rotation rate of 2 revolutions per minute. The display shall operate satisfactorily in the unstabilized mode, when the compass control is inoperative.

- Means shall be provided to allow the equipment to be verified while in use, to detect drops in performance from the original calibration, and to allow accurate tuning in the absence of targets.

- Full anti clutter functions, to defeat sea, rain and other forms of precipitation, shall be provided, which can be switched off and are fully adjustable. Automatic clutter control may be provided but must allow to be switched off.

C) Operation

- The equipment shall be capable of being switched on and operated from the display position, and will become fully operational within 4 minutes maximum of initial power on. A standby position will be provided from which the radar can be brought to full operating condition within 15 seconds. Radar controls shall be

accessible and easy to identify and use. If symbols are used, they should comply with the international radar control symbols, outline in the Canadian Coast Guard documentation on radar regulations.

- Where a true motion function is implemented, the resolution and accuracy of the display shall be equivalent to that described above. Under no condition, shall the origin move away from the display centre, by more than 75% of the total screen radius. Automatic reset may be provided.

- The antenna system, shall be installed in such a way and in such a location that the design efficiency is not substantially degraded.

- All radars operated in the X-Band, shall be capable of operating in the horizontal polarization mode. Override shall be provided for all signal processing functions that may prevent the discrimination of a radar beacon.

In addition to all of the above, the equipment will comply electrically with the "Ship Safety Electrical Standards, Transport Canada, Coast Guard, TP 127".

Most equipment on the market is compliant with these regulations, and our concern should focus on the minimum system requirements, outlined in A) governing rules. Compliance with the other requirements, should be verified by ascertaining that the

prospective equipment has been designed and built with these regulations in mind.

APPENDIX B

RFP Telefax Copy

INTRODUCTION

For the purpose of Ice navigation as well as the need for a backup radar, Canarctic recently purchased a cross-polarized X-band radar antenna.

This antenna will provide two channels of independent but related information. Since no commercially manufactured systems will be adequate for driving this device, we are now looking for a system that can be used in part or modified to suit our needs.

At the same time, we saw an opportunity to integrate the new system with the already existing shipboard systems, to yield a complete utility that will meet all requirements and lend itself to future needs.

A system block diagram was prepared to outline the proposed system. This outline is open to discussions and/or suggestions.

The basic components requirements are as follows:

- -One X-Band transceiver
- -One X-Band receiver for the cross polarized channel
- -Two daylight displays that can be used as control stations
- -Four dual signal buffers to ensure proper signal distribution
- -One trigger lead signal selector (interference suppression)
- -Two control station selectors
- -Three signal source selectors
- -One logarithmic IF strip for the S-Band radar video generation
- -All necessary interfaces for interconnections

Some or most of these components will be commercially available, and others will have to be designed from scratch.

This radar system will be considered a prototype and will serve as a test platform for related radar system research project. These project will aim at defining and testing the next generation of Arctic Marine Radars, that will be used by the increasing Arctic shipping community.

For the purpose of evaluating the different systems available, the following information would be needed and will be requested from most radar manufacturers:

-A quotation on the proposed components or system
-A comprehensive first draft of proposal for the system, describing the general characteristics of the system components
-Full standard characteristics of the system components
-Full technical documentation for the proposed components

The full technical documentation of the components is necessary to evaluate the degree to which the devices comply to our requirements. These requirements cover the full range of construction, functionality, specifications, including the adequacy of the documentation as well as customer technical support from the manufacturer.

It is understood that some of the requested documentation might be proprietary information until the actual purchase and Canarctic will not disclose the information to any third party without the written consent of the supplier.

The specifications outlined in the enclosed list are general in nature and supplemental information will be supplied on request.
The system installation is scheduled for early January. Time is thus a critical factor.

COMPONENT SPECIFICATIONS

GENERAL SPECIFICATIONS:

-The components and installation will comply in full to the Coast Guard Standards for Navigating Appliances and Equipment (1983) regulations and the I.M.O. regulations.

MAIN TRANSCEIVER:

-maximum power output; 50 Kw
-minimum power output; 25 Kw
-power requirements; 120/220 Volts AC, 60 Hz.
-frequency band; X Band
-the magnetron should be located in the transceiver unit

CROSS POLARIZED RECEIVER:

-must be fitted with transmit/receive switch, to be controlled by main transceiver.
-should provide capability of tuning with main transceiver or be fitted with external tuning control and indicator.
-frequency band; X Band of the same frequency as main transceiver
-same general performance as that of main transceiver

DISPLAY UNITS:

-should be of daylight display type
-should include all controls needed to use as a master station
-should be compatible with DECCA signal format

SIGNAL BUFFERS:

-should have sufficient capacity to feed all units specified in supplied block diagram, plus two additional loads
-should have a minimum bandwith of a minimum of 18 Mhz (3dB)
-should be constructed with standards similar to the main transceiver

TRIGGER LEAD SELECTOR:

-will provide selection of lead transmitter for interference avoidance

-will allow selection of either selector, independent operation, or external source

-if the selected lead station is not in function, the slave station will automatically revert to internal source

-when external source will be selected, the selector will provide rate limiting to prevent overload of the magnetrons

DISPLAY SELECTORS:

-will provide connection to three different signal sources of the selected display units

-will provide signal scaling and format translation to ensure compatibility between systems of different make

-will automatically revert to default source after power failure

-will provide local indication of signal source

CONTROL UNIT SELECTORS:

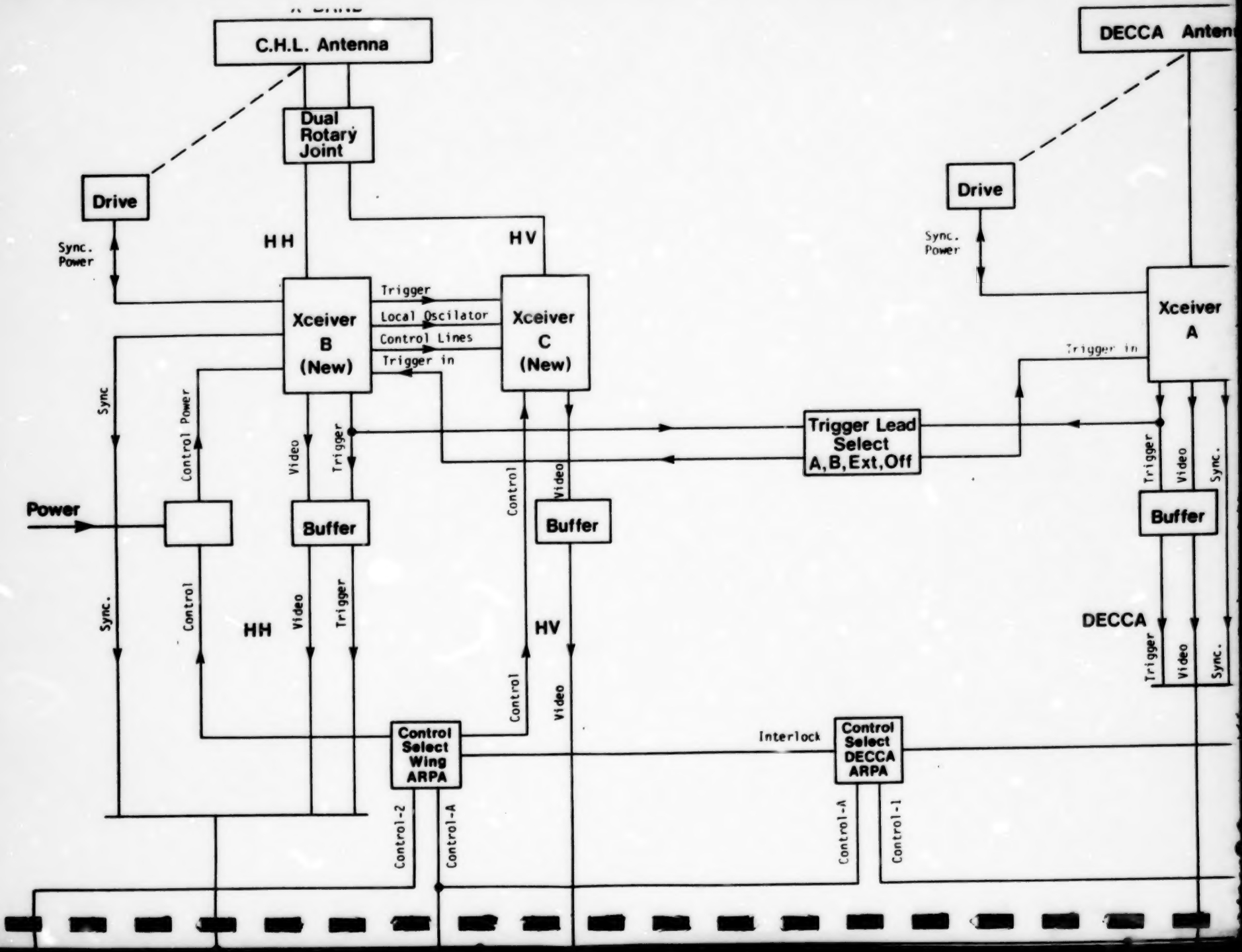
-will permit the selection of the control station

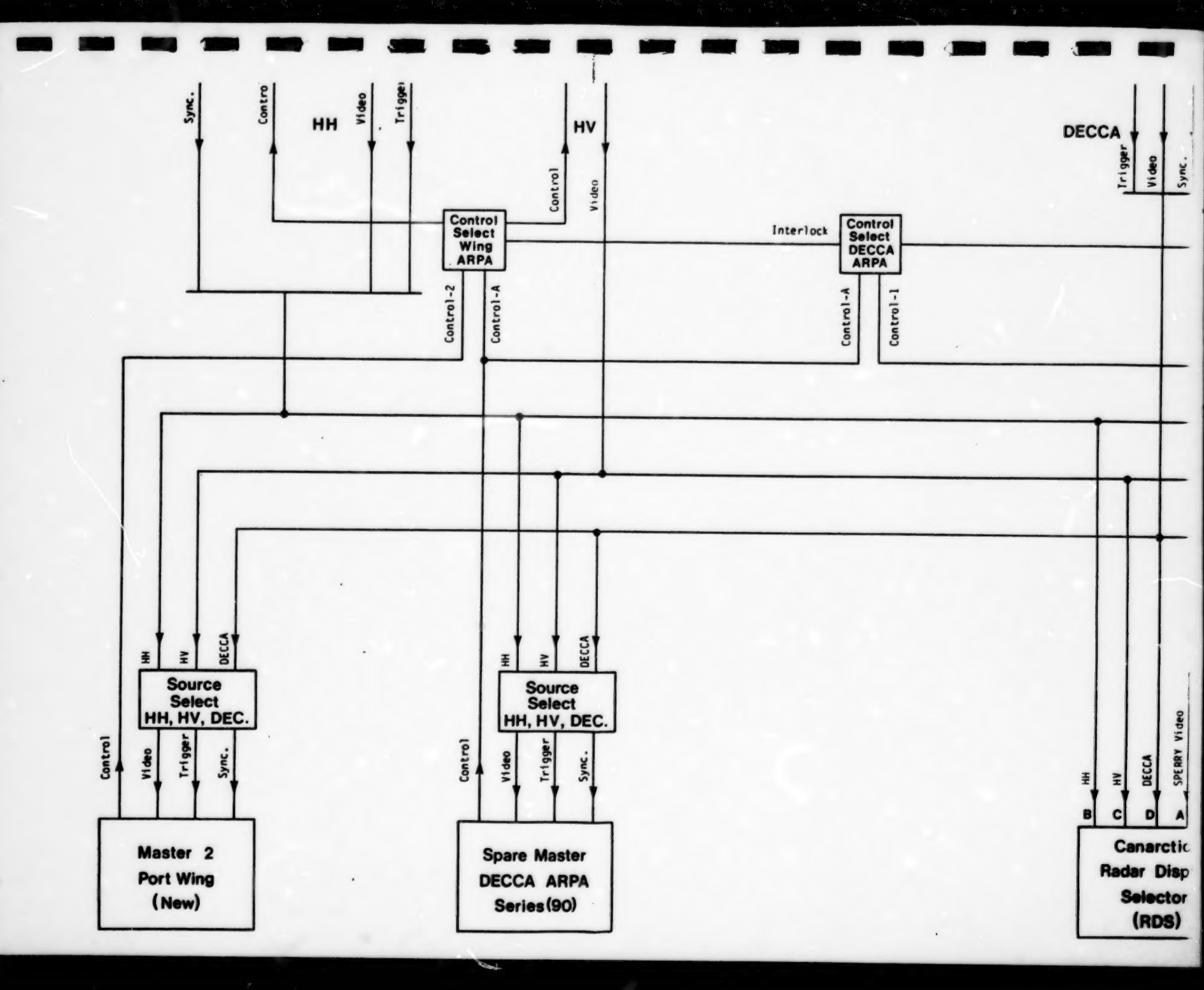
-will automatically revert to default station after power failure

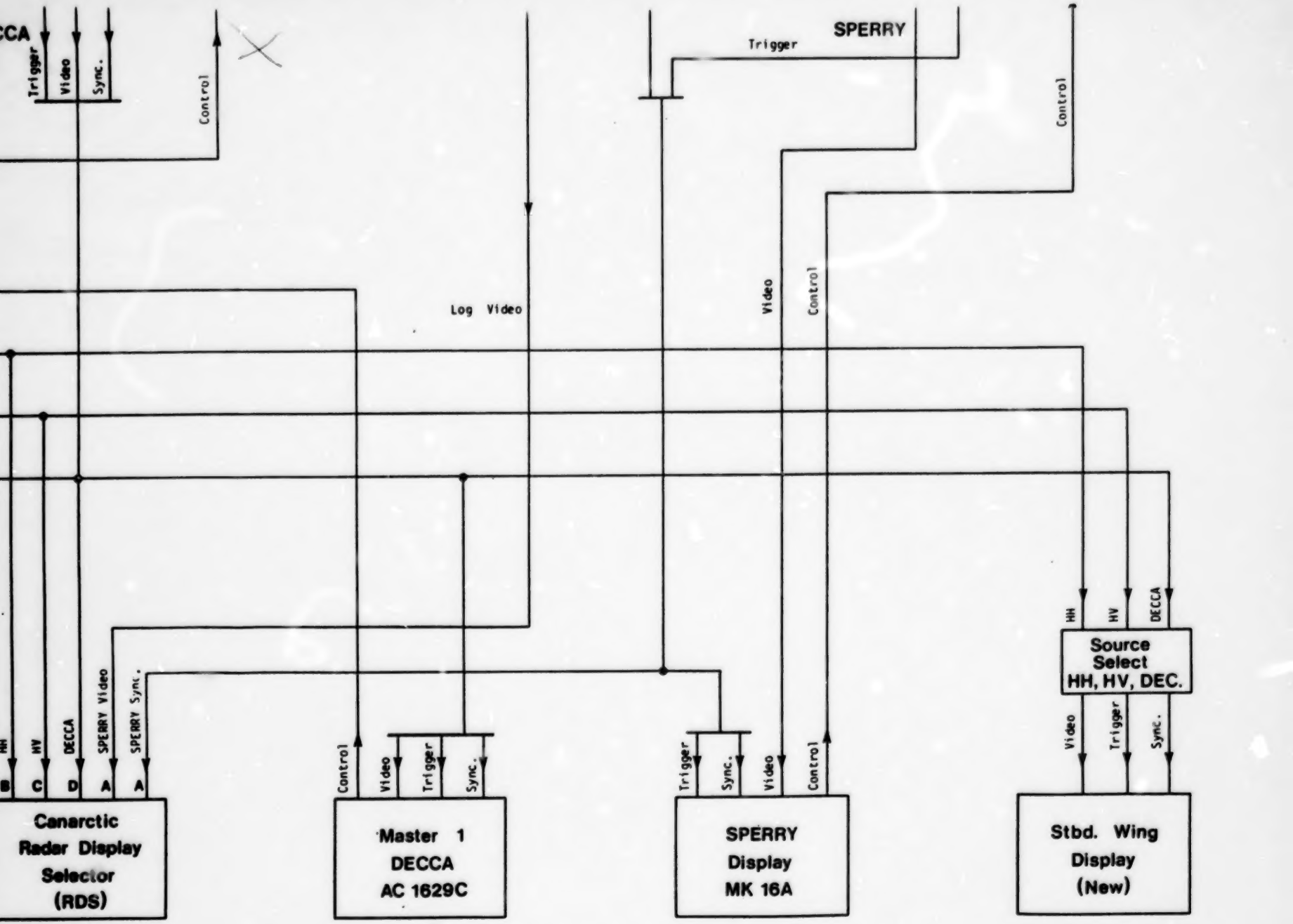
-will provide all necessary safeguards for switch-over

-will include interlocks to prevent the control of two transceivers from the spare station

-will provide all signal translation to ensure compatibility between units of different make


C.H.L. Antenna
Dual Rotary Joint
Drive
Sync. Power
HH
HV
Xceiver B (New)
Xceiver C (New)
Trigger
Local Oscilator
Control Lines
Trigger in
Sync
Control Power
Video
Trigger
Control
Video
Power
Buffer
Buffer
Sync.
Control
HH
Video
Trigger
HV
Control
Video
Control Select Wing ARPA
Control-2
Control-A
DECCA Anten
Drive
Sync. Power
Xceiver A
Trigger in
Trigger Lead Select A,B,Ext,Off
Trigger
Video
Sync.
Buffer
DECCA
Trigger
Video
Sync.
Interlock
Control Select DECCA ARPA
Control-A
Control-1


Sync.
Contro
HH
Video
Trigger
HV
Control
Video
DECCA
Trigger
Video
Sync.
Control Select Wing ARPA
Interlock
Control Select DECCA ARPA
Control-2
Control-A
Control-A
Control-1
HH
HV
DECCA
Source Select HH, HV, DEC.
Control
Video
Trigger
Sync.
HH
HV
DECCA
Source Select HH, HV, DEC.
Control
Video
Trigger
Sync.
HH
HV
DECCA
SPERRY Video
B
C
D
A
Master 2 Port Wing (New)
Spare Master DECCA ARPA Series(90)
Canarctic Radar Disp Selector (RDS)


CCA
Trigger
Video
Sync.
Control
SPERRY
Trigger
Control
Log Video
Video
Control
HH
HV
DECCA
Source
Select
HH, HV, DEC.
Video
Trigger
Sync.
HH
HV
DECCA
SPERRY Video
SPERRY Sync.
B
C
D
A
A
Control
Video
Trigger
Sync.
Trigger
Sync.
Video
Control
Canarctic
Radar Display
Selector
(RDS)
Master 1
DECCA
AC 1629C
SPERRY
Display
MK 16A
Stbd. Wing
Display
(New)

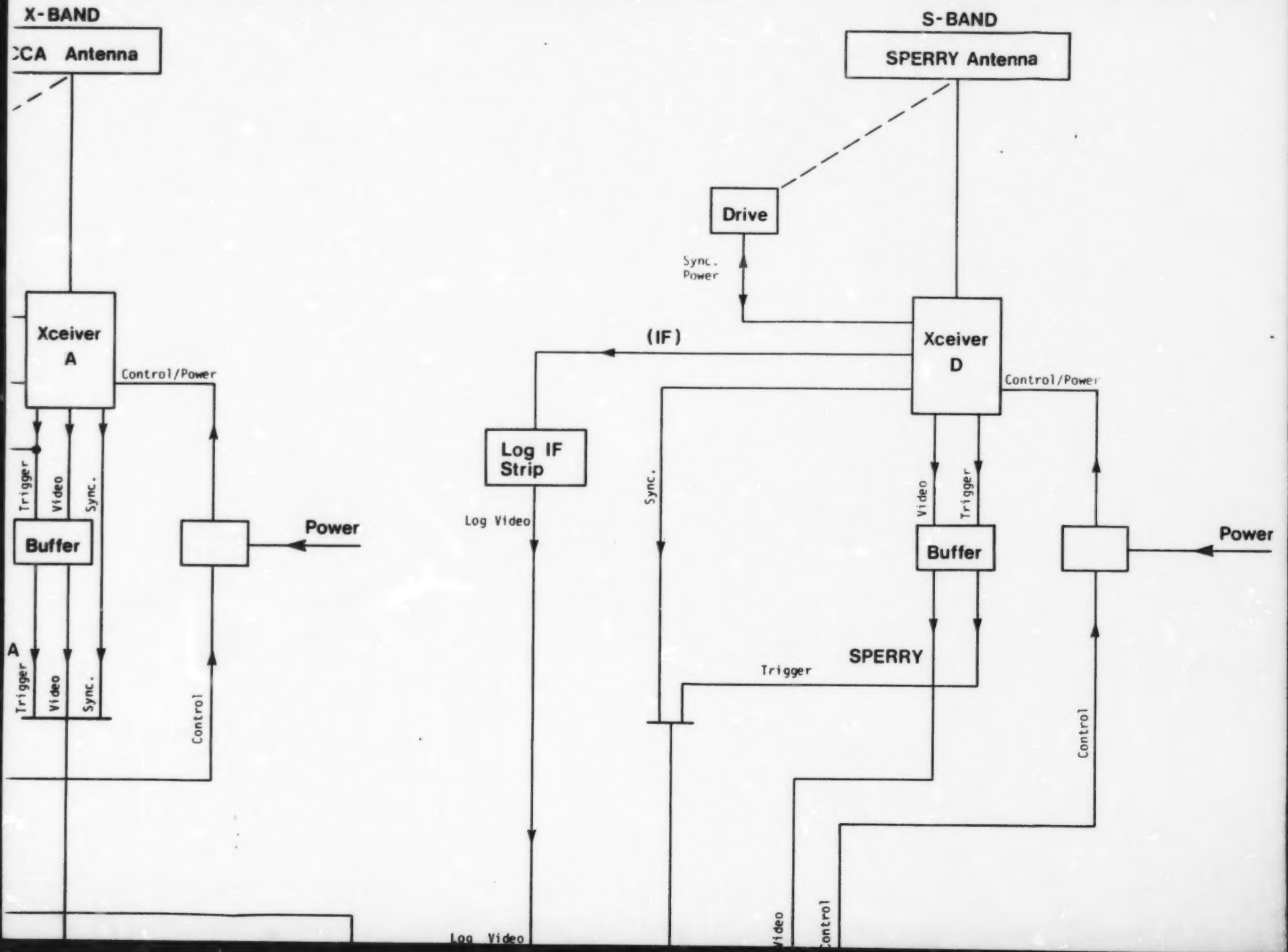
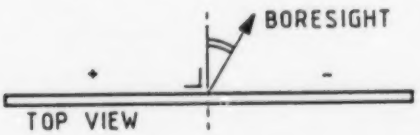

X-BAND
CCA Antenna
Xceiver A
Control/Power
Trigger
Video
Sync.
Buffer
Power
A
Trigger
Video
Sync.
Control
S-BAND
SPERRY Antenna
Drive
Sync.
Power
(IF)
Xceiver D
Control/Power
Log IF Strip
Log Video
Sync.
Video
Trigger
Buffer
Power
SPERRY
Trigger
Control
Log Video
Video
Control

TABLE 1

ANTENNA SPECIFICATIONS

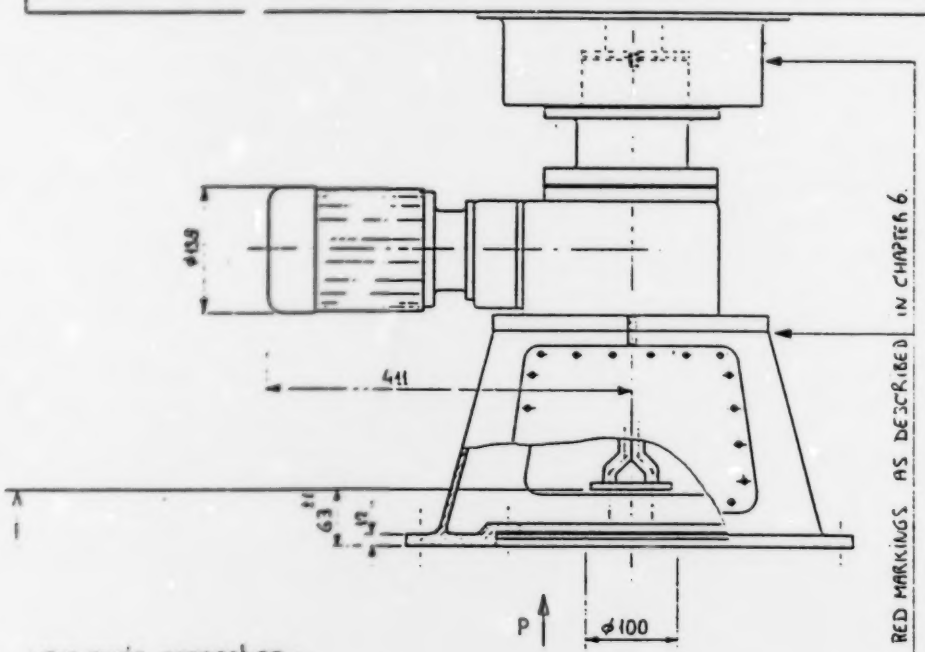
1.	FREQUENCY BAND	: 9350 - 9400 MHz
2.	POLARIZATION	: Horizontal & Vertical
3.	HORIZONTAL BEAMWIDTH (H/V)	: 0.95° ± 0.1°
4.	VERTICAL BEAMWIDTH (H/V)	: 18.0° ± 2.0°
5.	SIDE LOBE SUPPRESSION	: >26 dB
6.	ANTENNA GAIN (H/V)	: >31.5 dB
7.	V.S.W.R. INCLUDING ROTATING JOINT (H/V CHANNEL)	: 1.30:1 max
8.	SQUINT	: -3.25° nominal



9.	PEAK INPUT POWER:	
	- ANTENNA (BOTH CHANNELS)	: 200 kW
	- ROTATING JOINT H-CHANNEL	: 200 kW
	- ROTATING JOINT V-CHANNEL	: 50 kW
10.	ISOLATION BETWEEN BOTH CHANNELS	: >30 dB
11.	WEIGHT	: 60 kg
12.	DIMENSIONS LxWxH	: 2450 x 385 x 315 mm
13.	MAX. WINDSPEED (operational and survival)	: 185 km/h = 100 knots

ø2430 ROTATION AREA

antennalength : 2450

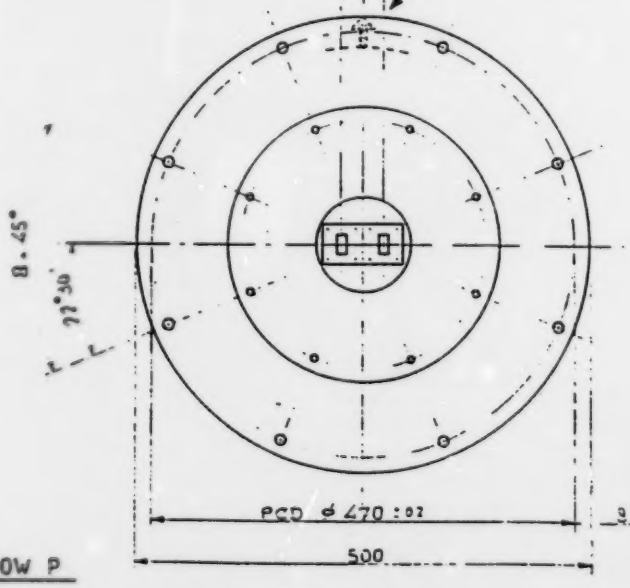


RED MARKINGS AS DESCRIBED IN CHAPTER 6.

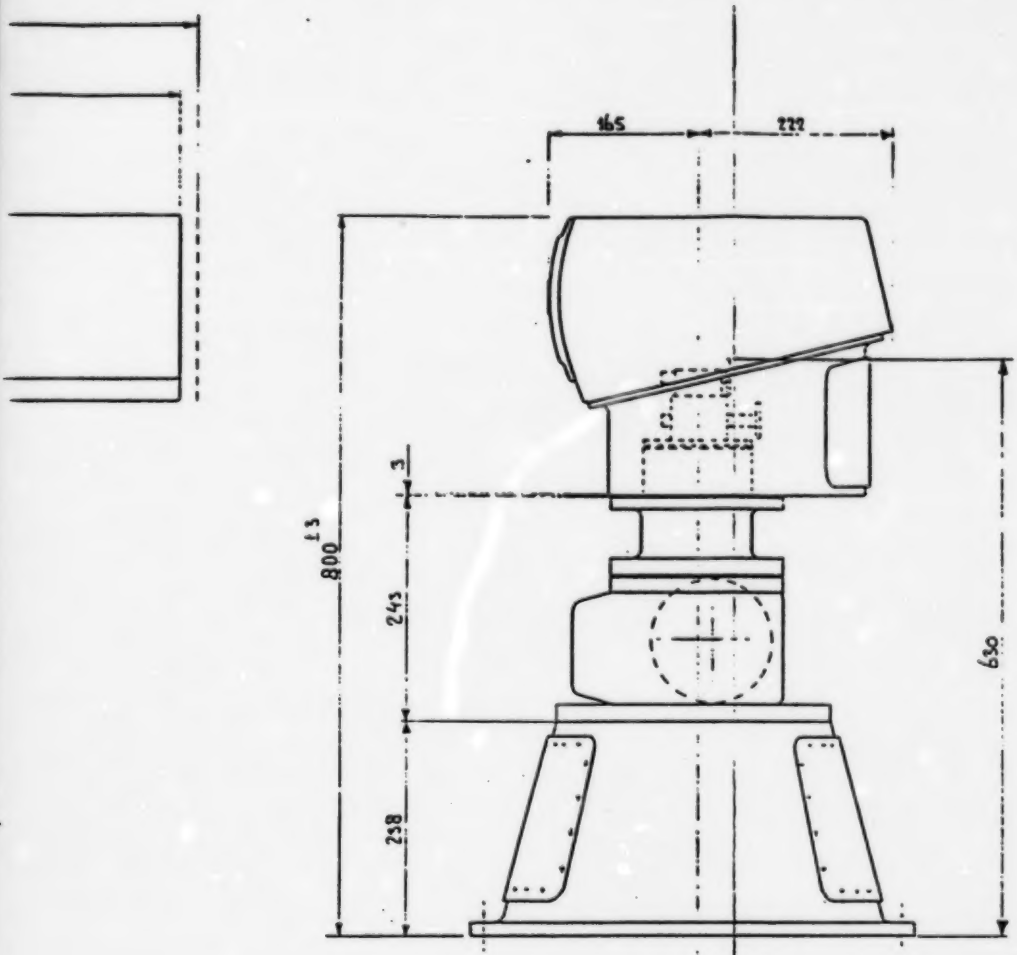
FRONT VIEW

wave guide connection :
Flanges in acc. to 154 IEC - PBR 100

45 ∢ waveguides



VIEW !!! ACC. WITH ARROW P



SIDE VIEW

TOTAL MASS : 135 KG ±3

Aantal	Stuk-nummer	Benaming	Opmerkingen	Tekening nr. afm. nummer	Materiaal	Ruwe afmetingen	Mogelijk	Datum overtaling	Norm
Schaal 1:5		Datum		Projectie		Afwerking			
Getek.		11-6-/87		TOLERANTIES.					
Gecontroleerd									
Gezien									
Benaming	ANTENNA TYPE SHV 30 B WITH GEARBOX AND SUPPORT								
0	MILIEU TOEGEVOEGD								
Wijziging	Datum	Omschrijving	CHRISTIAAN HUYGENSLABORATORIUM.. NOORDWIJK AAN ZEE – HOLLAND			Formaat A2	Tekeningnr. CANARCTIC.		
							FIG. 3		

erence

CHRISTIAAN HUYGENSLABORATORIUM B.V.

MANUAL FOR INSTALLATION AND MAINTENANCE

ANTENNA SYSTEM SHV-30-B

CANARCTIC

1. GENERAL

The antenna system consists of:

1.1 The antenna

The antenna SHV-30-B is of the slotted waveguide type, comprising a set of two end-fed slotted waveguides. One with displaced longitudinal shunt slots (vertical polarization) and the other with inclined transverse shunt slots (horizontal polarization).
They are mounted in a special tee junction shaped configuration which feeds a corrugated horn, to produce two orthogonal polarized fan-shaped vertical radiation patterns which coincide.
Radiating elements and corrugated horn are supported by a rigid wing.
All metal antenna parts are constructed of corrosion-resistant aluminium and painted with several coatings.
The wing-like construction makes the antenna light-weight and gives it a low windage.
No special maintenance is required for the antenna.
For weather protection a plastic sandwich radome is used, consisting of two glass fibre reinforced epoxy layers separated by a foam core.

NOTE

This radome is transparent for electromagnetic radiation and must not be repainted without special measures.

The cental part of the antenna consists of a vertical pipe ended by a mounting flange. The pipe is provided with an access hatch on the rear side of the antenna to give easy access to the waveguide run.

NOTE

Due to the light-weight construction of the antenna it should be handled with care.
When transported or stored without crate, the best procedure is to let it rest upside down on cushions or blankets.
The antenna is made of thin aluminium sheet and is not suited to rough handling.

1.2 The drive-unit

Specification

Speed motor shaft	: approx. 1680 revs/min at 60 Hz mains
Speed main shaft	: approx. 24 revs/min
Reduction ratio	: 71.794 : 1
Temperature range	: -30^{o} C to $+50^{o}$ C
Motor power (mech.)	: 370 Watt
Bearing indication	: 1:1 coupled synchro receiver shaft

Description (see figure 2 and 4)

The drive-unit is designed for operation in rough sea climate.
An electromotor drives a three-stage reductor, the last stage being of the helical-worm gear type.
The standard drive-unit has been provided with special upper and lower flanges, integrated in the design.
The hollow shaft is fitted with sealing rings on both sides and a grease filled labyrinth on the topside.

On the lower side of the drive-unit a bracket mounted synchro has been coupled 1:1 to the mainshaft.
On the outside an oil-level check plug, a filter plug, a drain and a breather are situated.
All internal rotating parts are lubricated by a wet- sump system at a sufficient oil-level.
The main shaft and motor bearings are grease-filled for life.

1.3 Support

In general the support is used when the antenna drive-unit is to be mounted on top of a flat structure.

The support consists of a conical section with mounting flanges on either side.
The top mounting flange has been provided with an 'O'-ring to seal the joint with the lower drive-unit flange.
The bottom mounting flange of the support has been provided with 8 holes of 11 mm diameter to allow mounting with bolts M10.

Two hatches in the conical section give easy access to the synchro, the heading marker switch and the waveguide flanges.

2. DIMENSIONS

2.1 Antenna (see figure 3)

Length	: 2450 mm
Width	: approx 385 mm
Height	: approx 315 mm

2.2 Drive-unit (see figure 4)

Height	: 243 mm
Width incl. motor	: 507 mm
Width	: 233 mm

2.3 Support (see figure 3)

Diameter	: 500 mm
Height	: 238 mm

3. WEIGHTS

3.1 Antenna	: approx 60 kg
3.2 Drive-unit	: approx 60 kg
3.3 Support	: approx 13 kg

4. ACCESSORIES

4.1 Motor

Manufacturer	: Flender Cavex
Type	: FN 71
Rated Voltage	: 220 VAC Δ 60 Hz
Supply	: 3 f 220 VAC 60 Hz
Power (mech.), Rated current I_n	: 370 Watt at approx. 2.1 A
Power factor	: 0.68
Starting current	: Approx. 7.8 A
Rotational speed	: 1680 revs/min
Degree of protection	: IP 66
Insulation class	: F

4.2 Synchro

Manufacturer	: Muirhead
Type	: 23M1H1Q
Size	: 23
Power supply	: 115 V 400 Hz
Specification according to	: MIL-S-20708/45D

4.3 Two channel rotating joint

Manufacturer	: CHL
Type	: X-2K (acc. to drawing D 2340/14)
Frequency band	: 8800 - 9500 MHz
V.S.W.R.	: <1.15
WOW	: <1.02
Insertion loss	: Approx 0.2 dB
Isolation between channels	: >70 dB
Max. power : H-channel	: 200 kW, 200 W mean
: V-channel	: 50 kW, 50 W mean

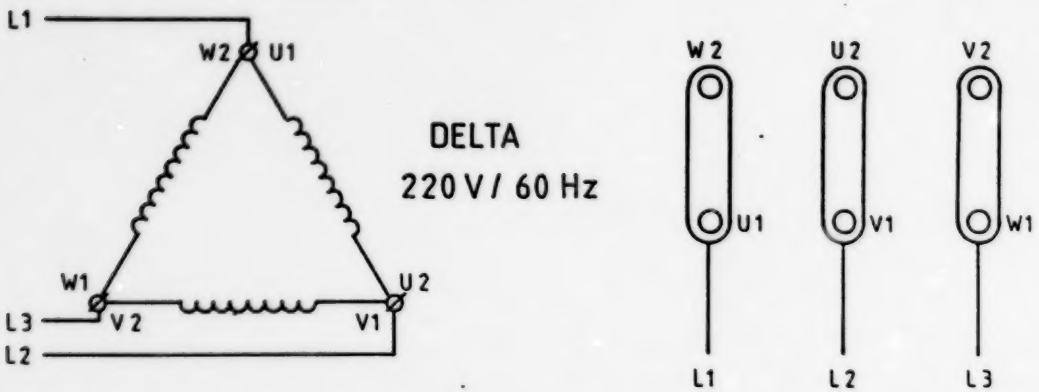
4.4 Reed Relay (Heading marker switch)

Manufacturer	: RS components Ltd.
Type	: 6 - RSR - A
Stock nr.	: 338-147
Current	: 500 m A
Life	: 10^8 operations

5. ELECTRICAL CONNECTIONS

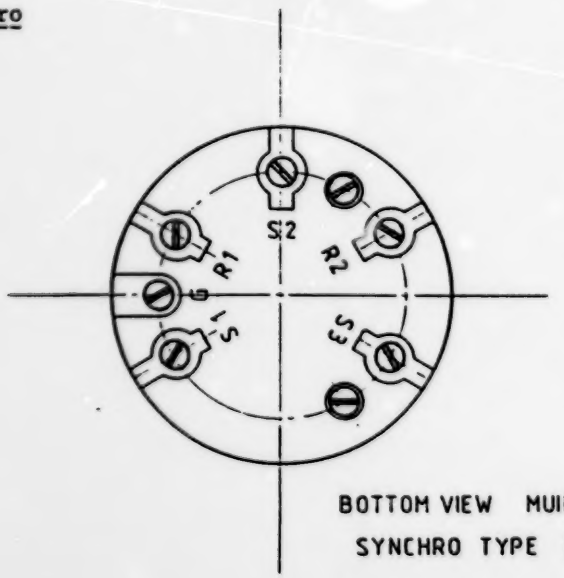
5.1 Motor

The supply terminals of the motor can be accessed after removing the cover of the terminal box.
Cable leads must be connected as follows:



A motor overload relay is recommended as protection against short circuits, overloading, phase failure etc.
The overcurrent relay must be adjusted to the correct nominal current.
The earthing conductor must be connected to the earth terminal provided.

5.2 Synchro



BOTTOM VIEW MUIRHEAD
SYNCHRO TYPE 23M1H1Q

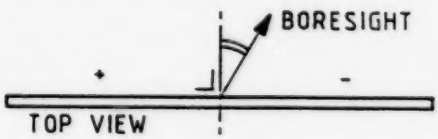
APPENDIX C

CHL Antenna Characteristics

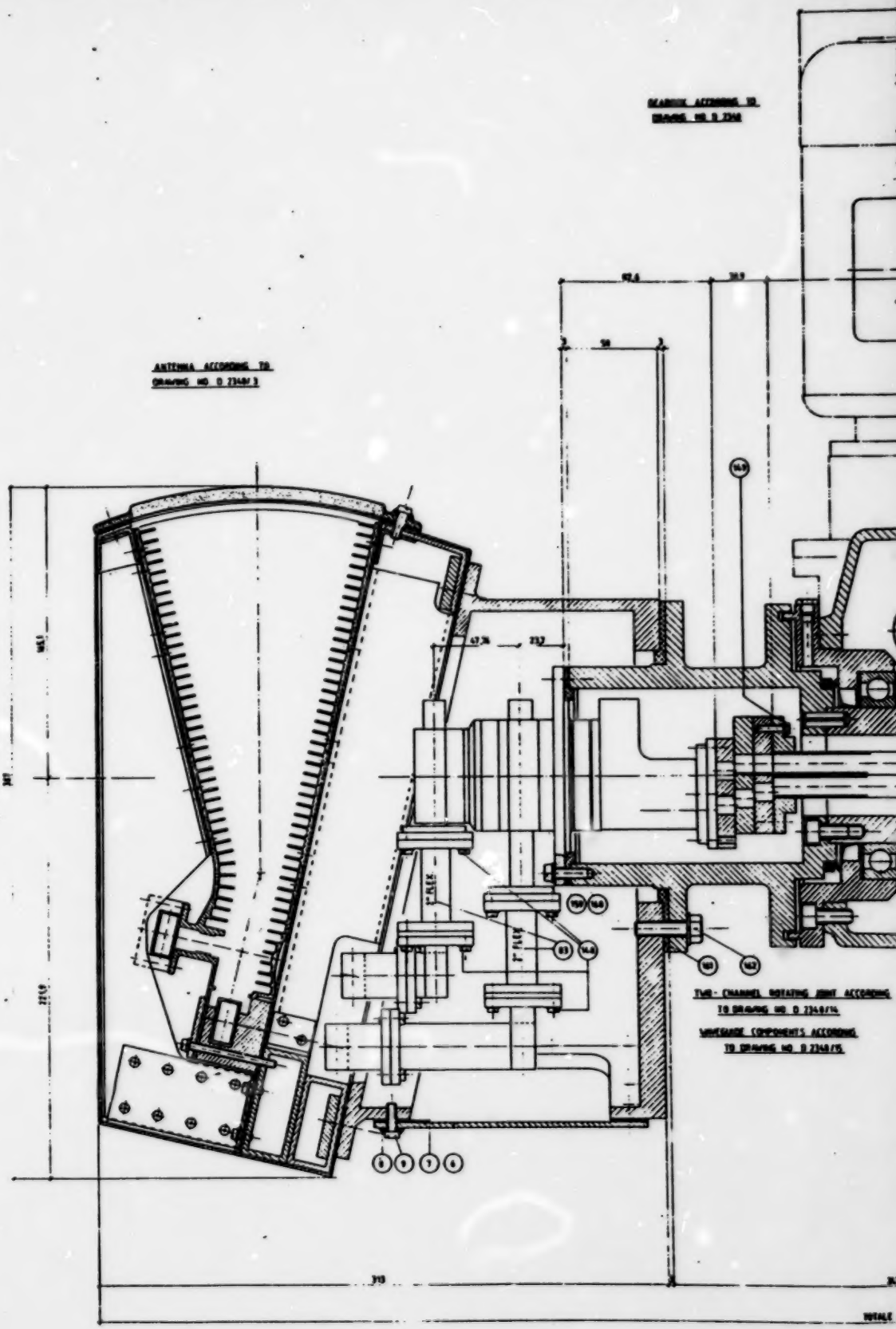
TABLE 1

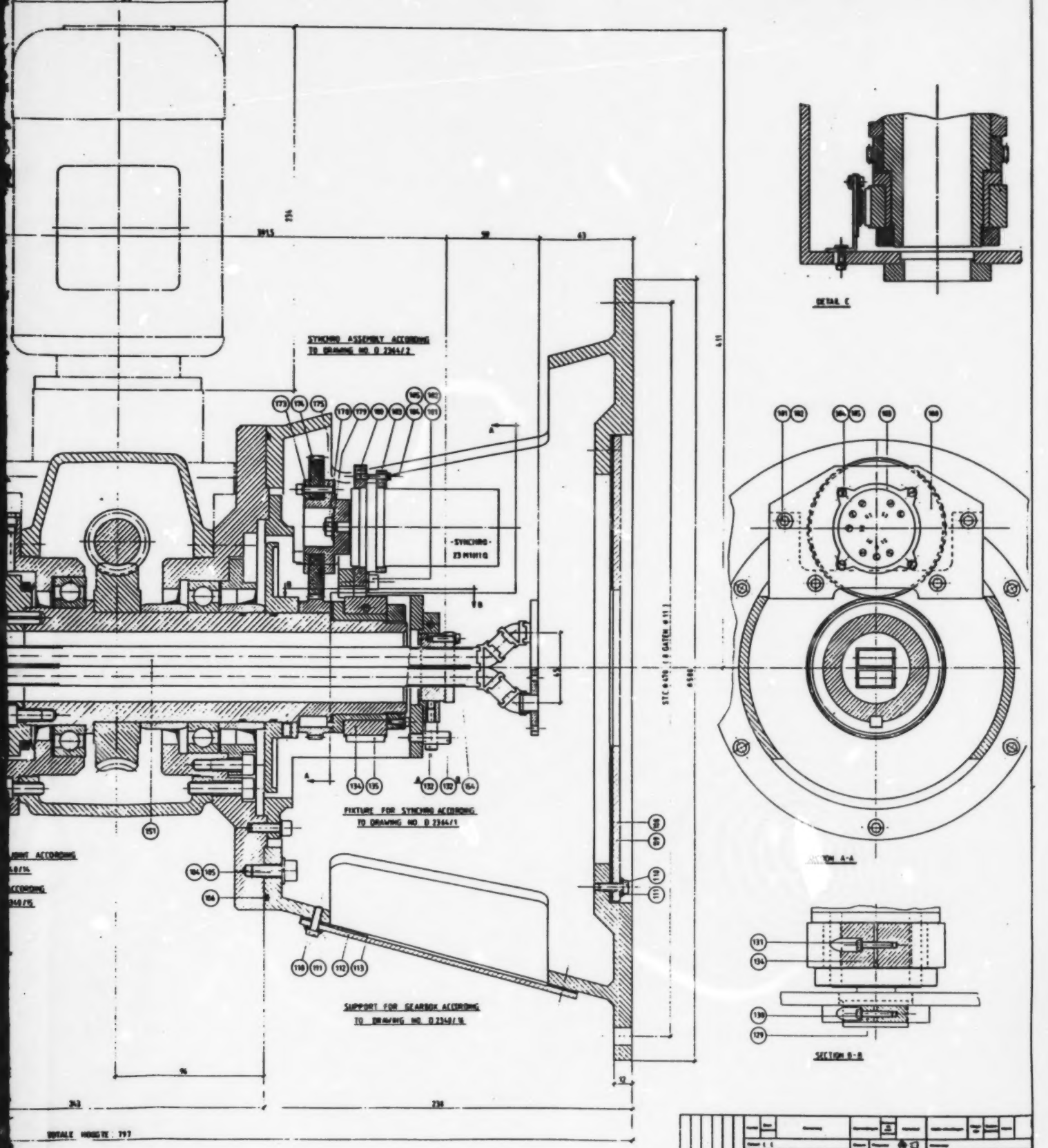
ANTENNA SPECIFICATIONS

1.	FREQUENCY BAND	: 9350 - 9400 MHz
2.	POLARIZATION	: Horizontal & Vertical
3.	HORIZONTAL BEAMWIDTH (H/V)	: 0.95° ± 0.1°
4.	VERTICAL BEAMWIDTH (H/V)	: 18.0° ± 2.0°
5.	SIDE LOBE SUPPRESSION	: >26 dB
6.	ANTENNA GAIN (H/V)	: >31.5 dB
7.	V.S.W.R. INCLUDING ROTATING JOINT (H/V CHANNEL)	: 1.30:1 max
8.	SQUINT	: -3.25° nominal



9.	PEAK INPUT POWER:	
	- ANTENNA (BOTH CHANNELS)	: 200 kW
	- ROTATING JOINT H-CHANNEL	: 200 kW
	- ROTATING JOINT V-CHANNEL	: 50 kW
10.	ISOLATION BETWEEN BOTH CHANNELS	: >30 dB
11.	WEIGHT	: 60 kg
12.	DIMENSIONS LxWxH	: 2450 x 385 x 315 mm
13.	MAX. WINDSPEED (operational and survival)	: 185 km/h = 100 knots

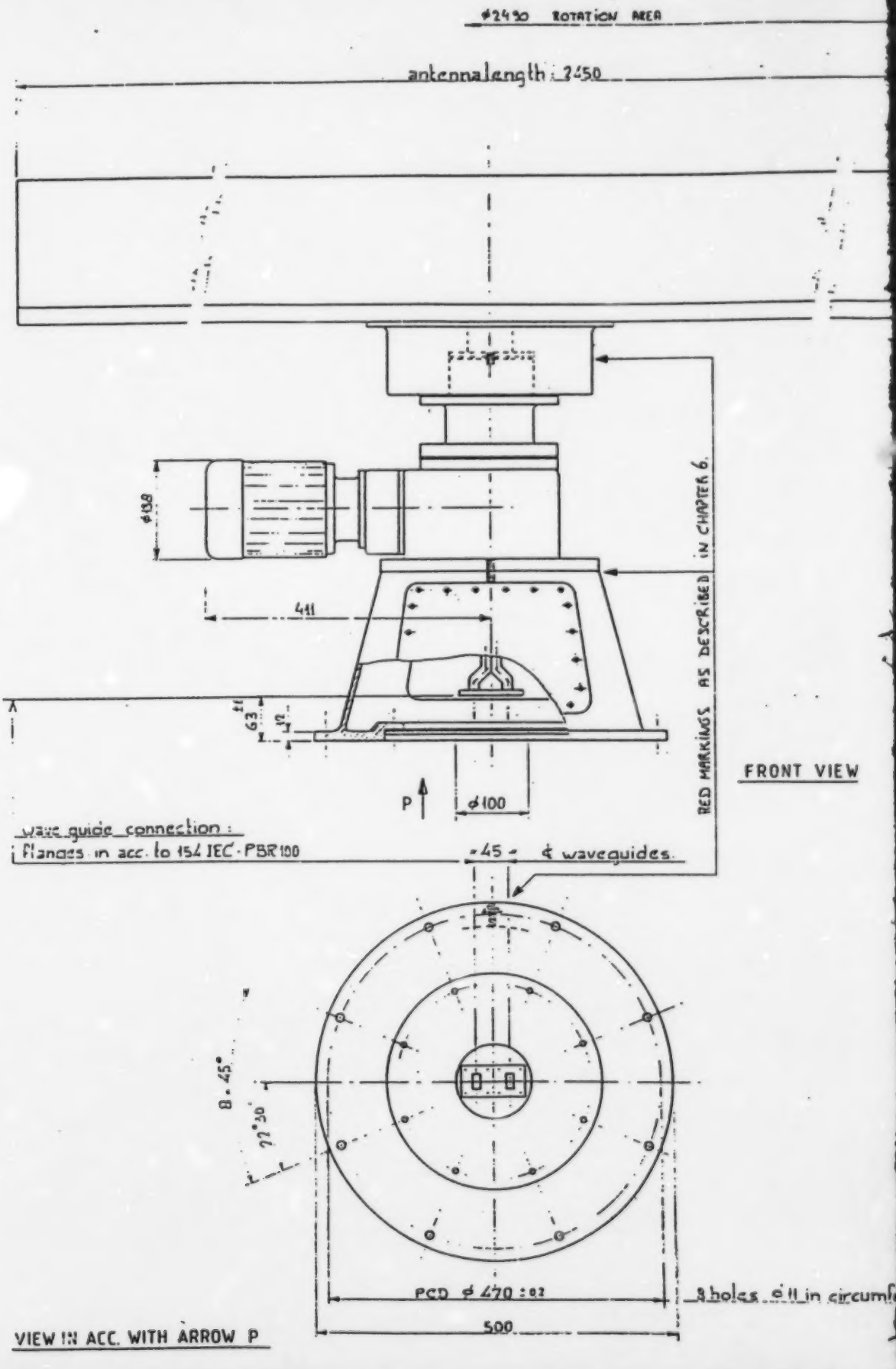

ANTENNA ACCORDING TO
DRAWING NO D 2348/3
THR - CHANNEL ROTATING JOINT ACCORDING
TO DRAWING NO D 2348/14
WAVEGUIDE COMPONENTS ACCORDING
TO DRAWING NO D 2348/15

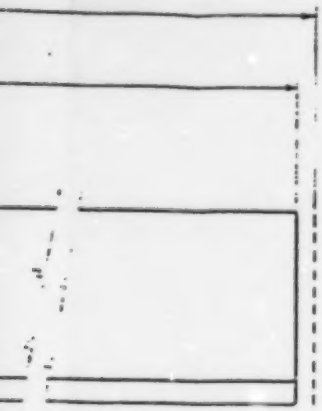

SYNCHRO ASSEMBLY ACCORDING TO DRAWING NO D 2364/2
-SYNCHRO-
FIXTURE FOR SYNCHRO ACCORDING TO DRAWING NO D 2364/1
SUPPORT FOR GEARBOX ACCORDING TO DRAWING NO D 2364/4
DETAIL C
SECTION A-A
SECTION B-B
TOTALE HOOGTE : 797

LAY-OUT ANTENNA ,GEARBOX & SUPPORT

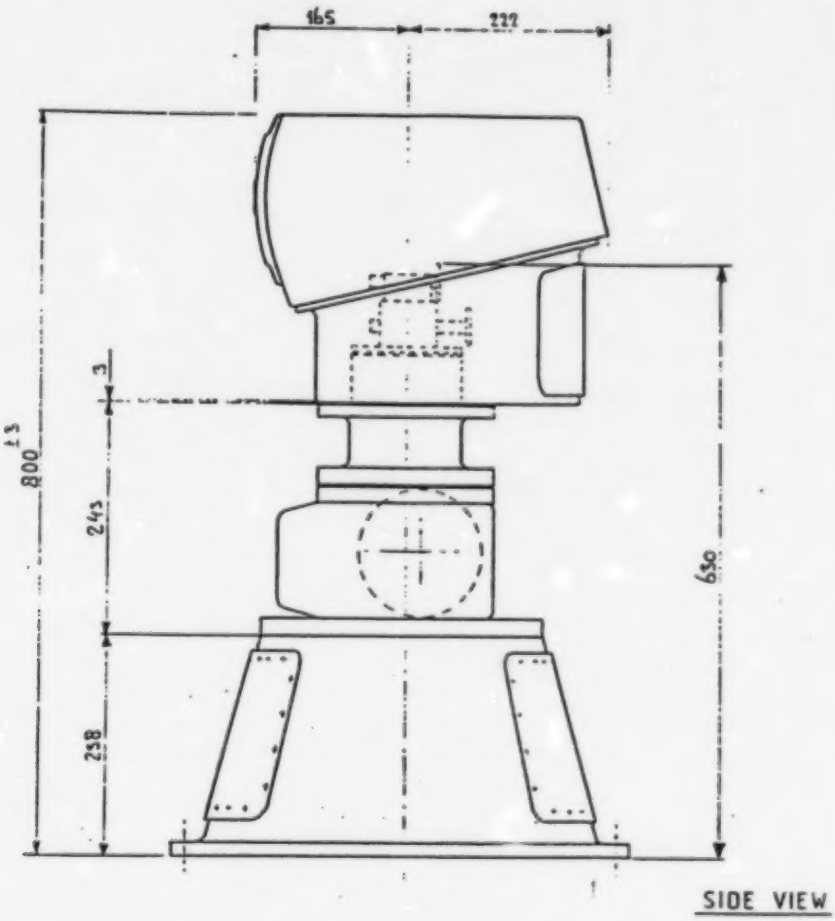
A0 D 2364

Figure C-1


ϕ2430 ROTATION AREA
antennalength 2450
ϕ138
411
63
12
P
ϕ100
RED MARKINGS AS DESCRIBED IN CHAPTER 6.
FRONT VIEW
wave guide connection :
Flanges in acc. to 154 IEC-PBR100
-45 - 4 waveguides
8 - 45°
22°30'
PCD ϕ 470 ± 03
8 holes ϕ11 in circumf
500
VIEW IN ACC. WITH ARROW P



VIEW



SIDE VIEW

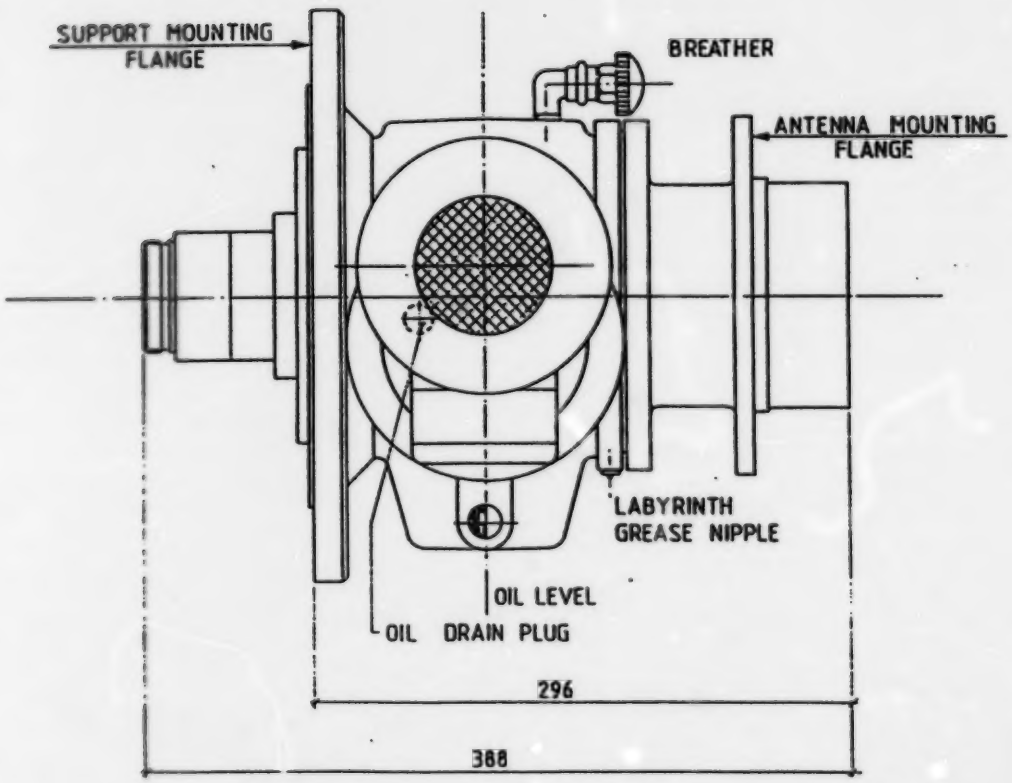
TOTAL MASS : 135 KG ±3

Aantal	Stuk-nummer	Benaming	Opmerkingen	Bewerkingen zie stuk-nummer	Materiaal	Ruwe afmetingen	Magazijn	Bestelnummer	Norm	
Schaal 1:5		Datum			Projectie		Afwerking			
Getek.		12/87			TOLERANTIES					
Gecontroleerd										
Gezien										
Benaming	ANTENNA TYPE SHV 30B WITH GEARBOX AND SUPPORT									
Wijziging	Datum	Onderkenning	CHRISTIAAN HUYGENSLABORATORIUM HOORDWIJK AAN ZEE – HOLLAND			Formaat A2	Tekeningnr. CANARCTIC.			

MATEW TOEGEVOEGD

Figure C-2
Layout

circumference


SUPPORT MOUNTING FLANGE
BREATHER
ANTENNA MOUNTING FLANGE
LABYRINTH GREASE NIPPLE
OIL LEVEL
OIL DRAIN PLUG
296
388

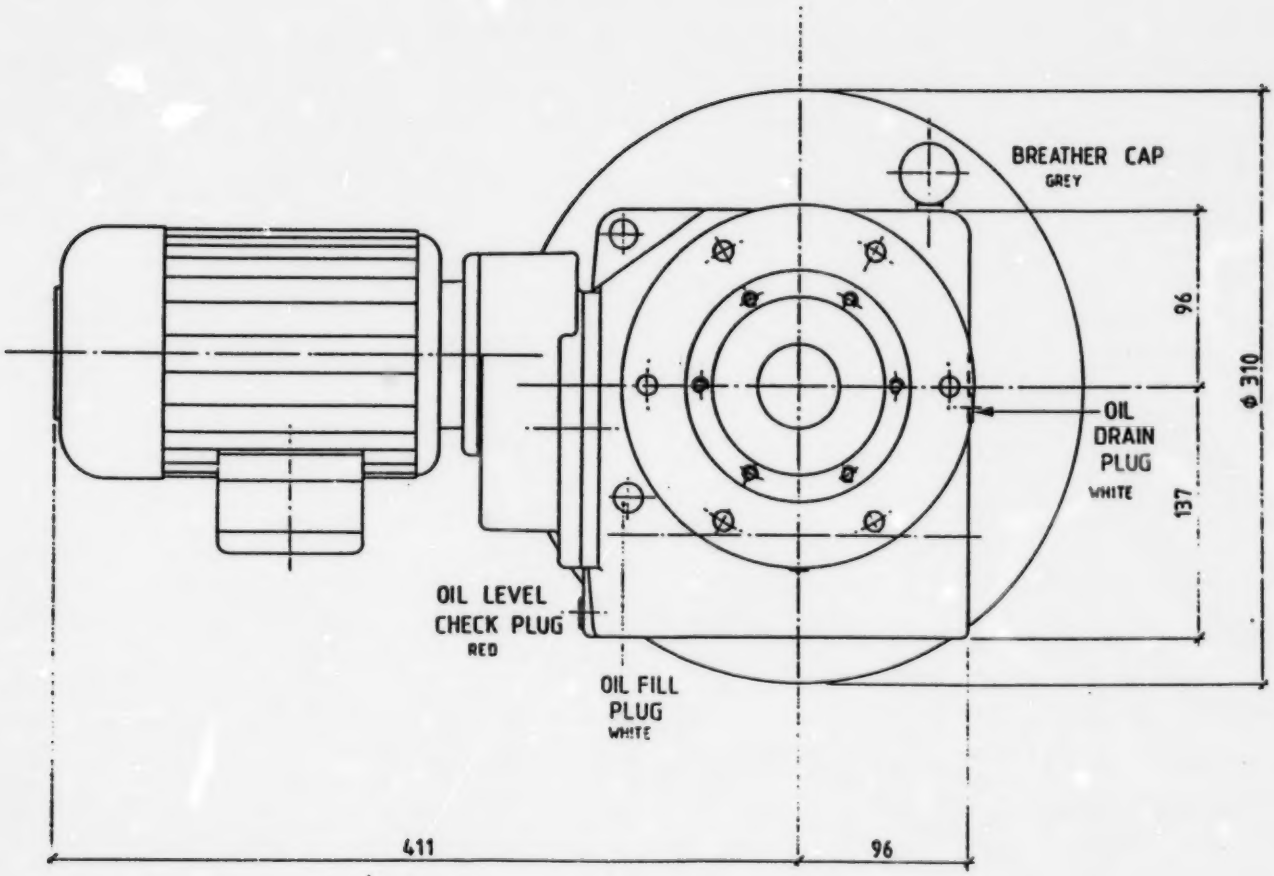


Figure C-3
Drive-Unit

APPENDIX D

Interfaces and Circuit Diagrams

Introduction

The implementation of the Arctic Marine Radar system on board the M.V. Arctic necessitated the development of a number of special circuits and various modifications. This Appendix describes in detail these circuits and modifications.

In order to interface the display to the RDS, the following modifications were implemented:

1) A sampler interface was designed to generate the required synchronizing signals.

2) Modifications were made to the Raytheon internal circuitry to facilitate the interface process.

3) Modifications were made to the RDS circuitry to generate resolver signals of the correct frequency.

4) A synchro reference driver circuit was built for the CHL antenna synchro transmitter.

5) A synchro signal allignement circuit was installed to allign the radar images from the different radar sources.

Raytheon PPI Display

The Raytheon PPI display azimuth decoding principle is different from most radar displays and therefore requires a special signal format for interfacing to the transmitting antenna.

Figure D-1 shows a block diagram of the Raytheon PPI display's internal decoding circuitry. A 1800 Hz signal is used to generate two related 900 Hz signals. One of the 900 Hz signals is processed to produce the resolver reference signal, while the other 900 Hz signal is used to demodulate the sine and cosine

signals returned from the antenna resolver transmitter. In the normal operating mode, the resolver exitation is 90 degrees out of phase with the sampling signals, so that the sampling will be made at the maximum amplitude of the resolver signals. This only occurs if the resolver excitation is provided by the display circuitry. In cases where the display is to be used as a slave to a master station, special circuitry in the Raytheon master provides adequate synchronizing signals.

Sampler Interface .

A special adaptor was designed to generate the sampling signals from the standard 900 Hz reference generated in the RDS. A block diagram of the adaptor is shown in Figure D-2. The circuit diagram for the adaptor is shown in Figure D-3.

The operation of the adaptor is straight forward and was implemented using low cost components. The resolver reference signal is AC coupled to a buffer amplifier/integrator. The effect of the integrator is to shift the incomming signal by 90 degrees in addition to filtering the incomming signal from incomming high frequency noise. A comparator transforms the phase shifted signal into a square wave of the same frequency. The square wave from the comparator is applied to a pulse generator that outputs a 50 uS positive pulse on each input signal low to high transition. In this manner, a sampling pulse is generated every time the incomming signal voltage reaches a peak. When properly interfaced to the Raytheon PPI display, the sample signal causes the sine cosine signals from the resolver to be latched and demodulated. The sampling interface was installed in the Raytheon display and

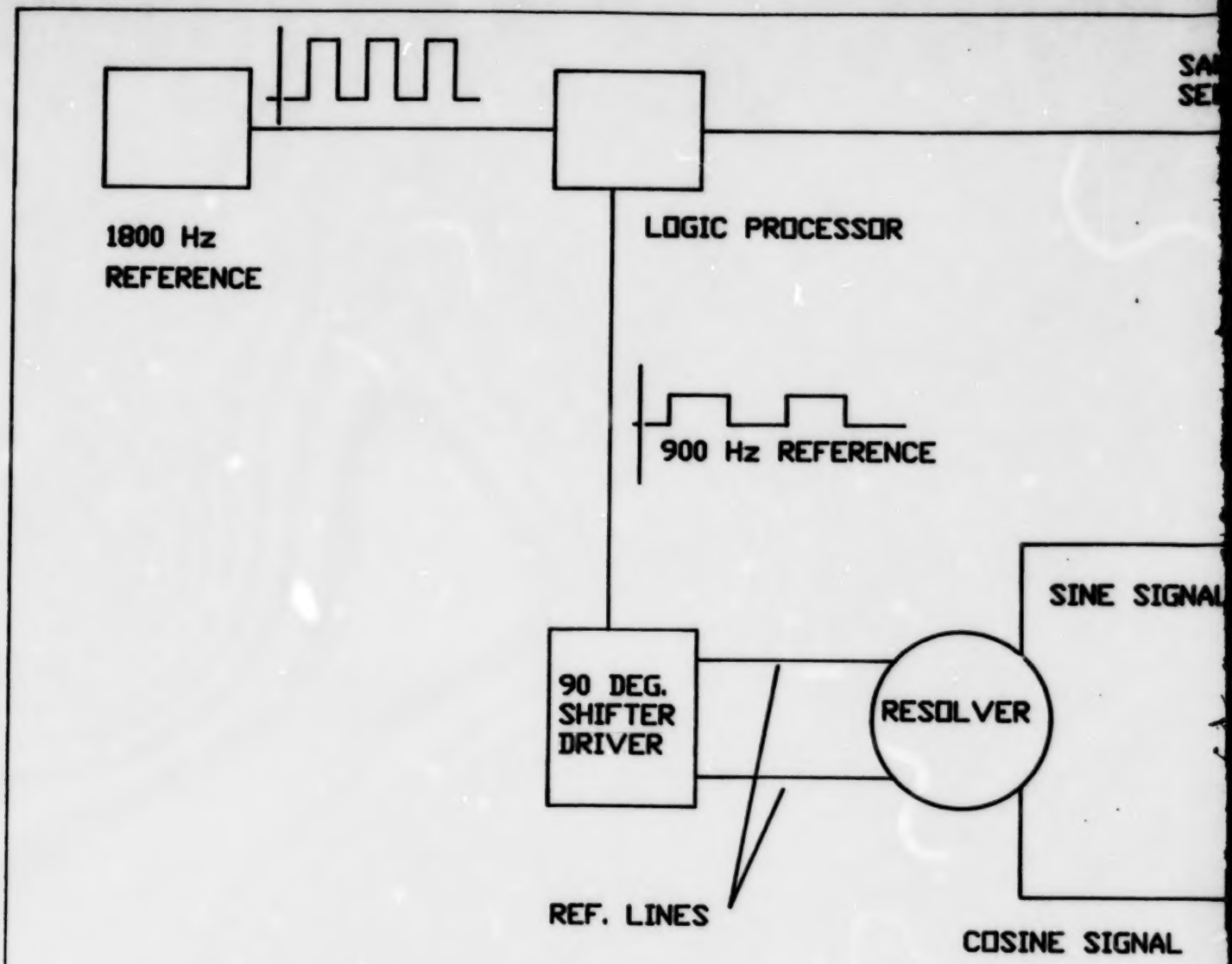
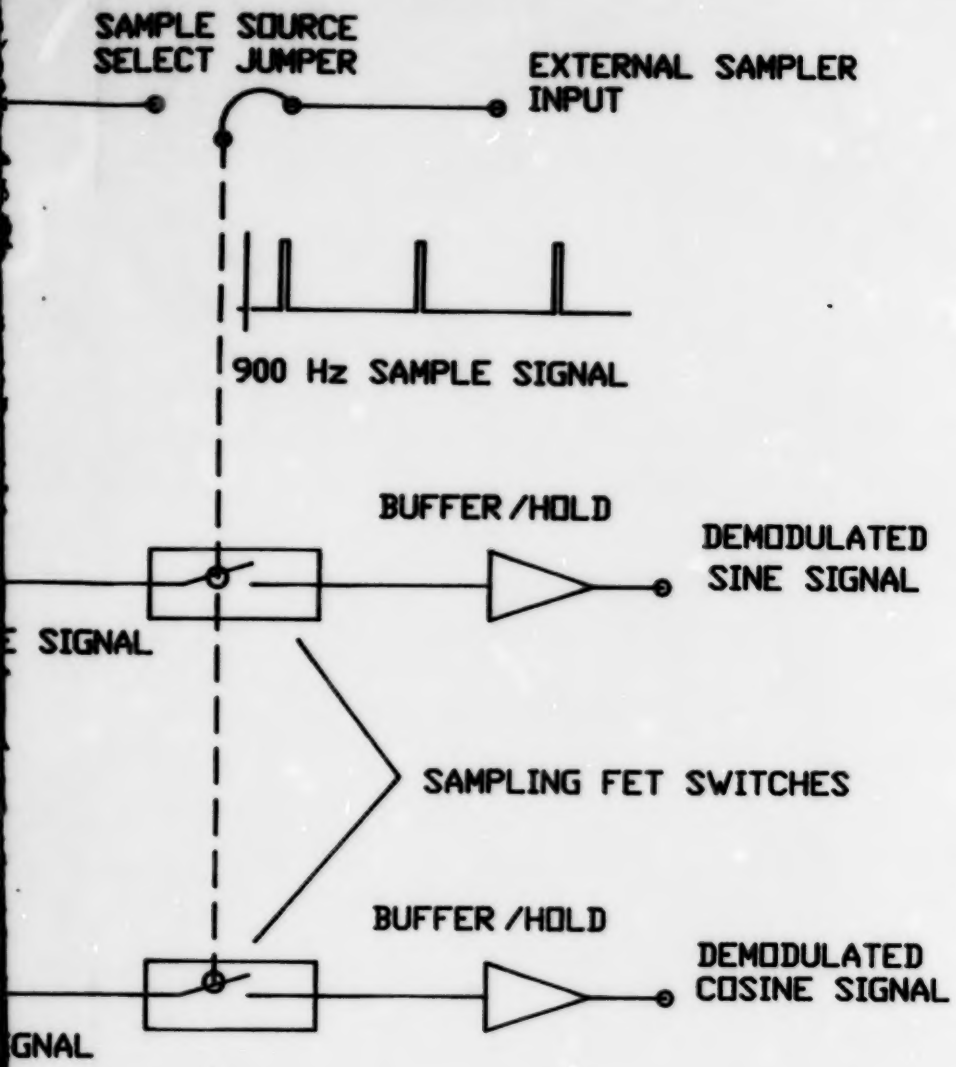


FIG. D-1: RAYTHEON PPI DISPLAY A
BLOCK DIAGRAM.



AY AZIMUTH DECODER

Figure D-1
Raytheon PPI Display Azimuth Decoder

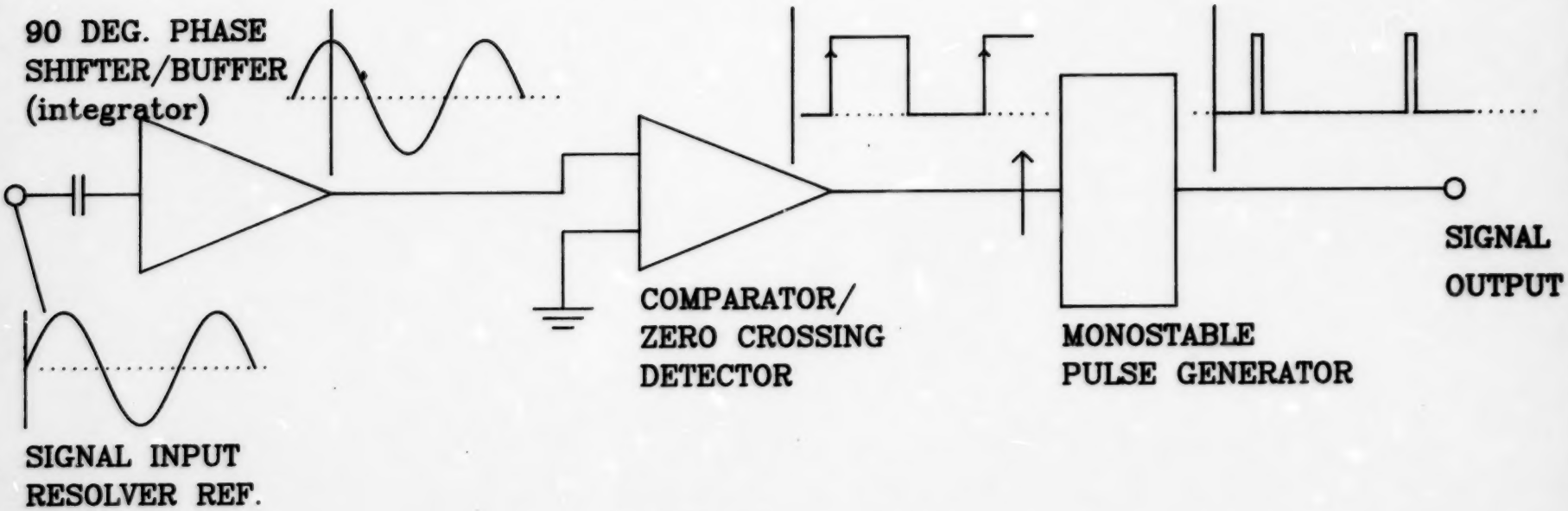


Figure D-2

RAYTHEON SAMPLER INTERFACE
BLOCK DIAGRAM

RAYTHEON DISPLAY
SAMPLER INTERFACE

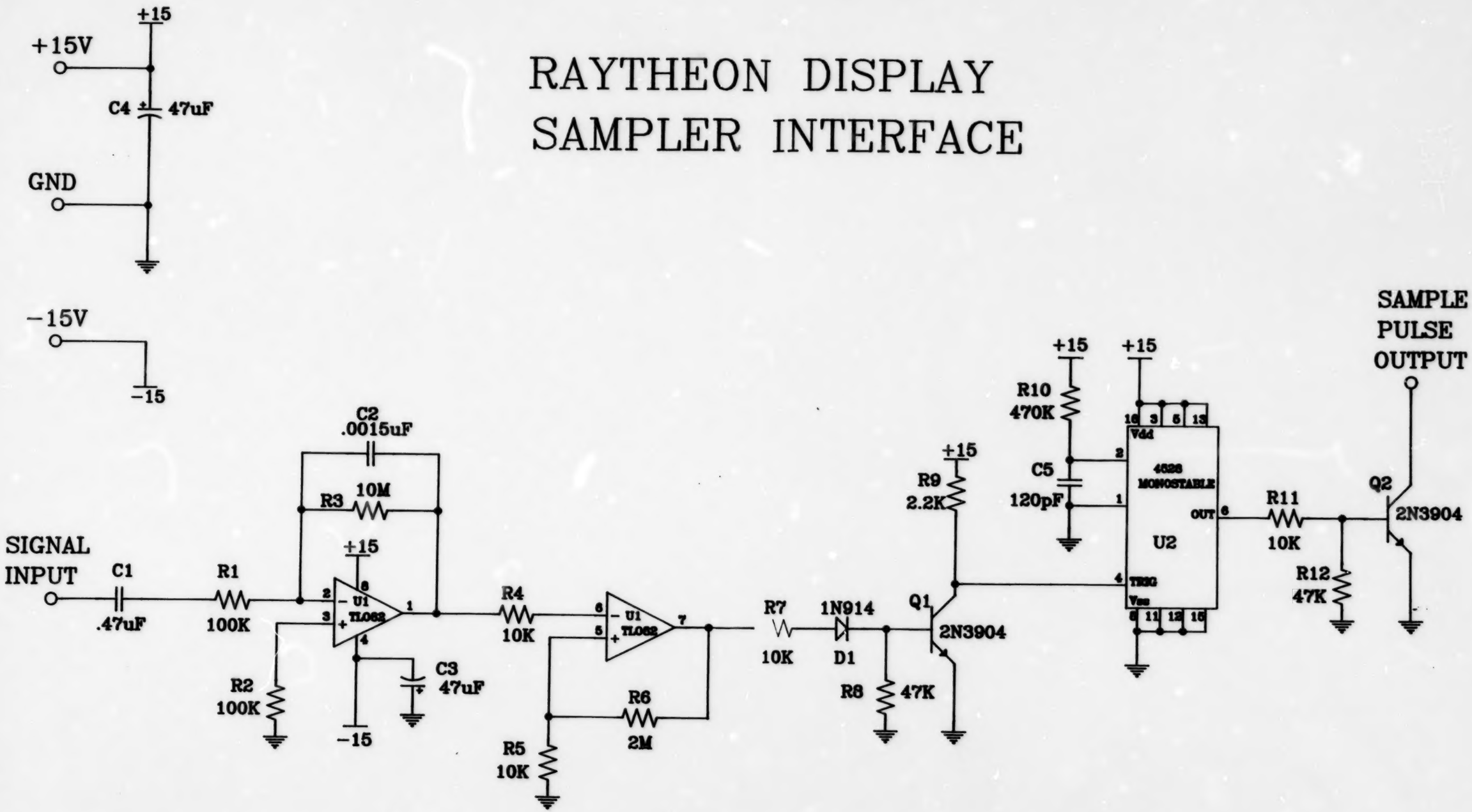


Figure D-3
Raytheon Display Sampler Interface

power to drive it taken from the display's internal circuitry. Figure D-4 shows the interface as installed in the display.

Figure D-4: Raytheon Display Sampler Interface

Raytheon PPI Display Circuit Modifications

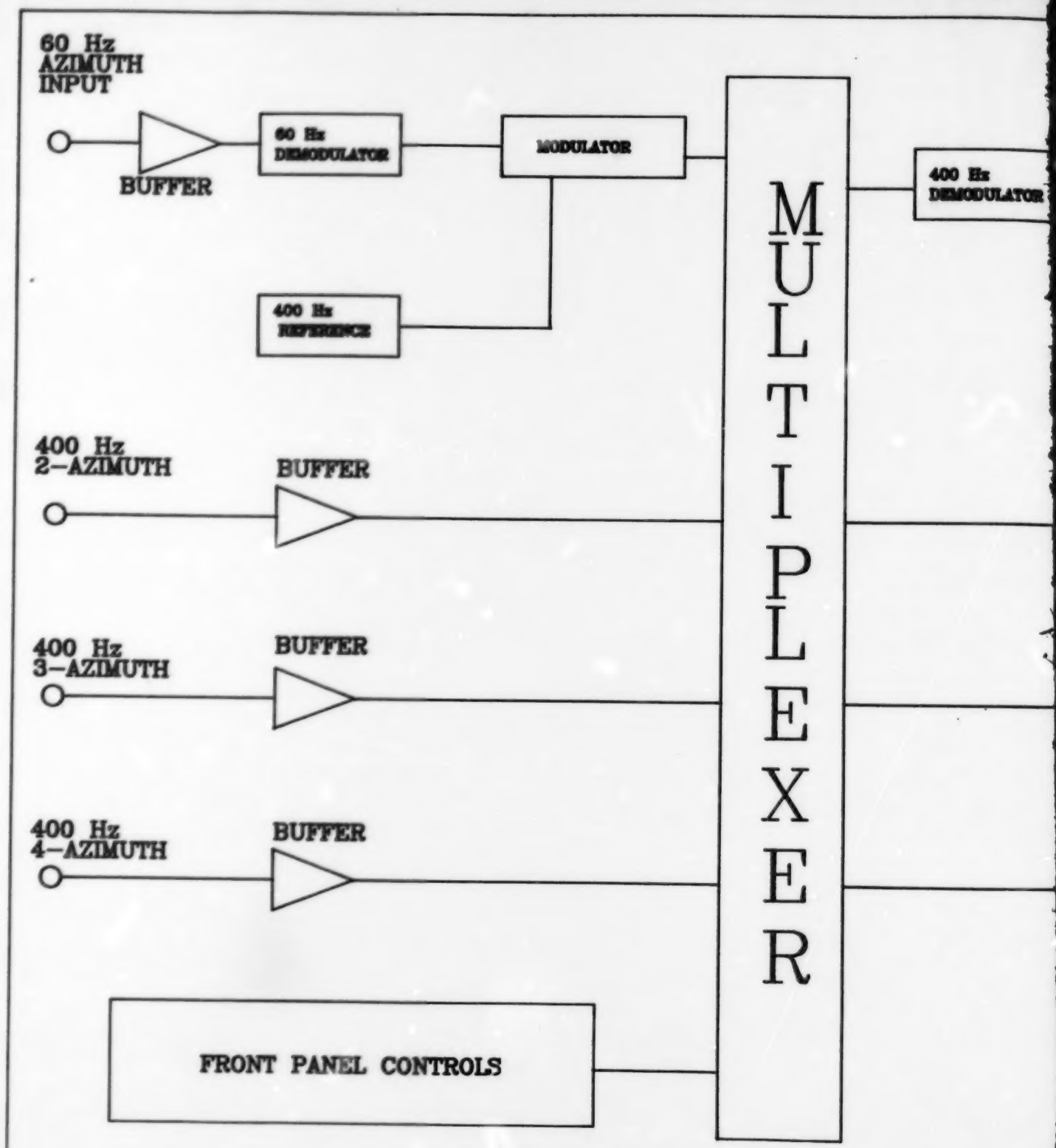
The slave signal normally generated from a master Raytheon display is a differencial pulse transmitted over two independant wires. This signal format was chosen by the manufacturer because of the better signal transmission characteristics over the long distances that are often encountered between master and slave stations.

In our particular case, the differential format was not necessary since the interface is located directly in the display. Internal circuitry inside the Raytheon display dealing with differential signals was disabled and bypassed, routing the special interface signals dirrectly to the demodulator circuitry. In so doing, the complexity of the interface was greatly reduced, and the connection requirements simplified.

RDS Modifications

The RDS output used to drive the Raytheon display was formerly formated to drive a JRC display which uses a 4 Khz reference for the azimuth signals. In all other respects, the interface requirements for the Raytheon display are identical to the JRC display. Therefore the RDS was modified to change the reference frequency to 900 Hz required by the Raytheon display.

Figure D-5 shows a block diagram of the RDS where output A was used to drive the Raytheon display. Each input to the RDS azimuth channels comprises 3 synchro lines plus 1 reference signal, represented on the block diagram by one line followed by a buffer. Output A demodulates the 400 Hz signals, recombines the synchro signals to produce the desired resolver information.


60 Hz
AZIMUTH
INPUT
BUFFER
60 Hz
DEMODULATOR
MODULATOR
400 Hz
REFERENCE
400 Hz
DEMODULATOR
400 Hz
2-AZIMUTH
BUFFER
400 Hz
3-AZIMUTH
BUFFER
400 Hz
4-AZIMUTH
BUFFER
FRONT PANEL CONTROLS
MULTIPLEXER

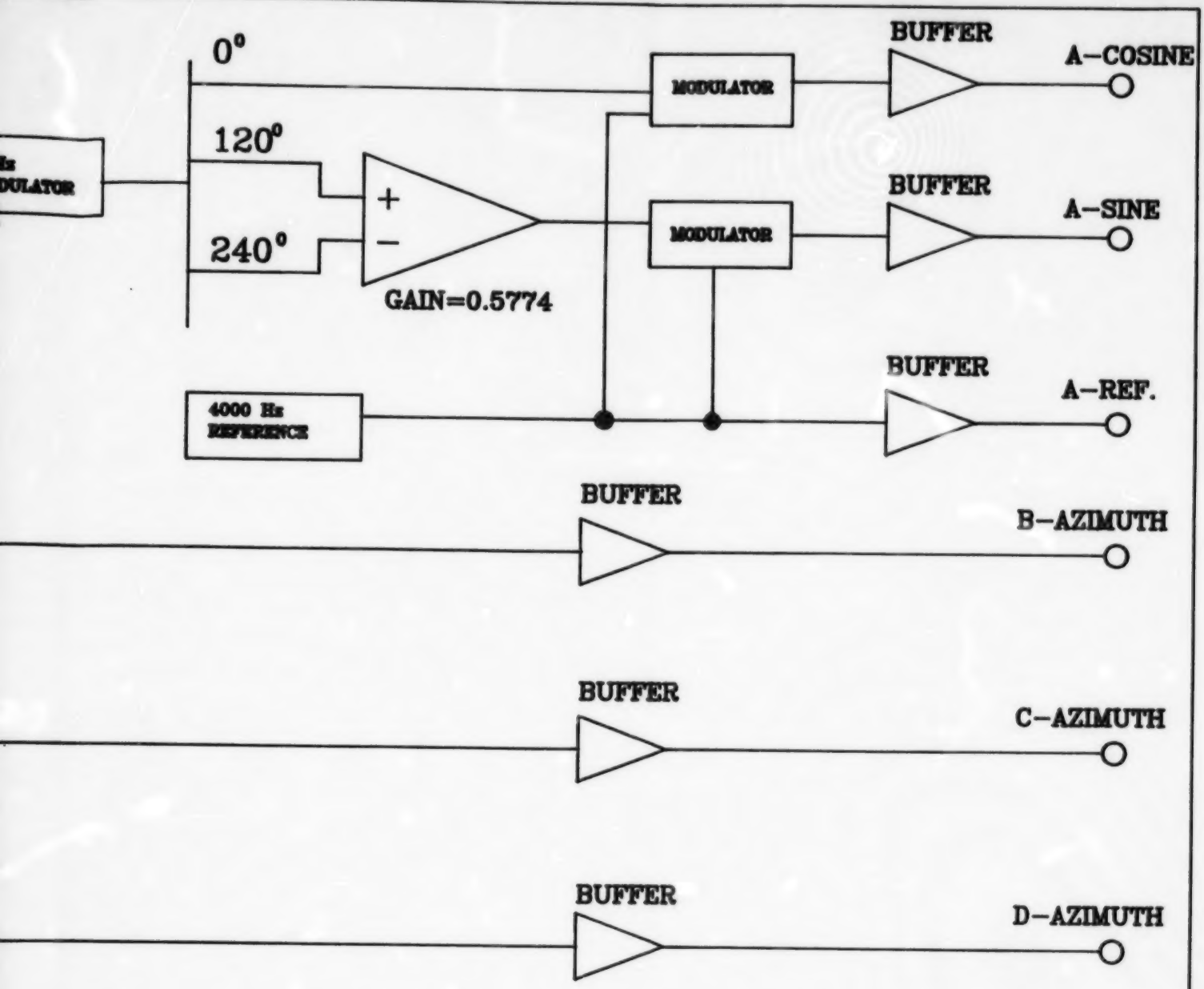


FIG.D-5: RDS BLOCK DIAGRAM

Figure D-5
RDS Block Diagram

Figure D-6 shows the shematic diagram of the relevant RDS section, where three capacitors were replaced to change the operating frequency. The components were changed as follows:

Component	From	To
C44	.022 uF	.1 uF
C47	.01 uF	.047 uF
C48	680 pF	.0033 uF

In addition to these changes, parallell connections were made to the front panel switches to implement remote operation of the RDS from the Raytheon display location. From the RDS, three sources of radar signals are now available to the port Raytheon display:

1) Decca X-Band radar
2) Sperry X-Band HH radar
3) Sperry X-Band HV radar

CHL Antenna Synchro Reference Driver

The Christiaan Huygens dual polarized antenna used on the Sperry X-Band radar, was delivered fitted with a synchro azimuth transmitter. The Sperry radar however uses a pulse technique to transmit azimuth information to the display, and is therefore not equiped to drive a synchro transmitter. In order to interface the antenna azimuth information to the RDS (and therefore to the rest of the SINSS radar displays), a synchro azimuth driver was required.

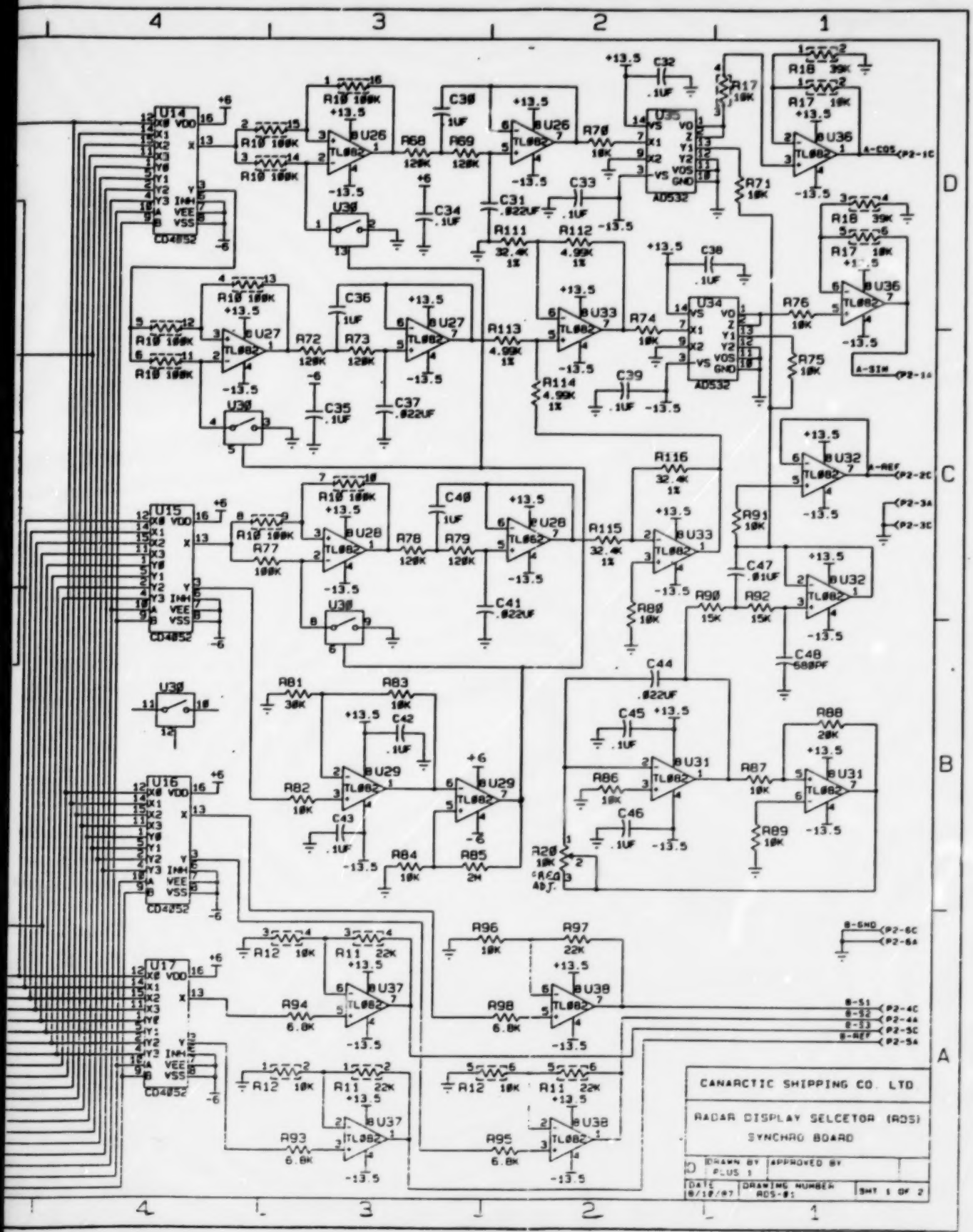


Figure D-6

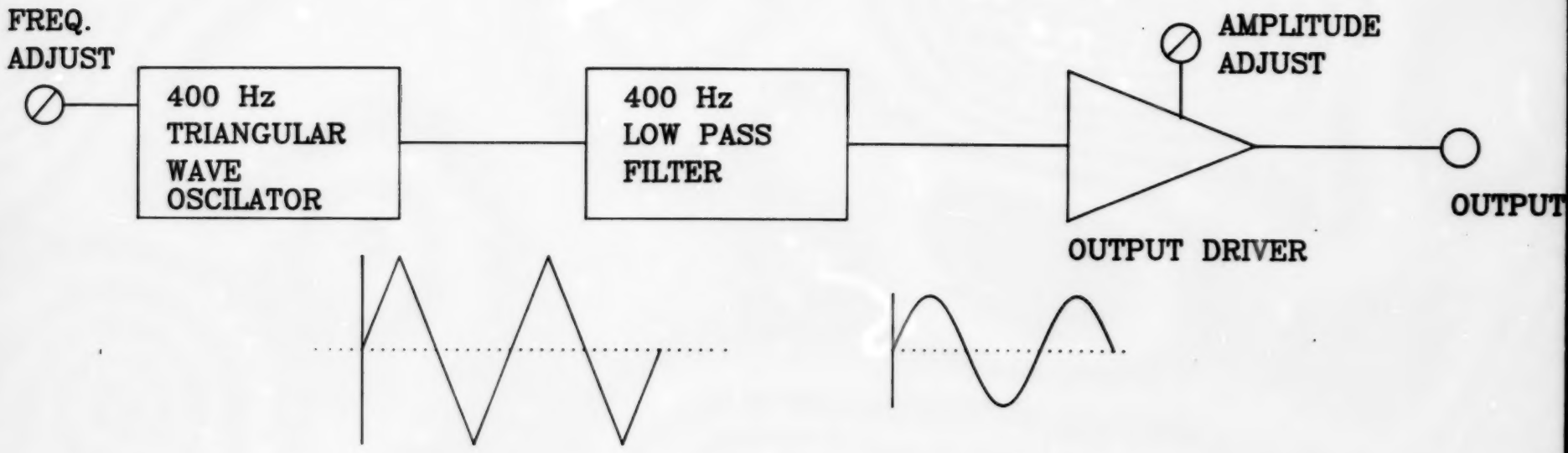
RDS Synchro Board

Figure D-7, shows a block diagram of the synchro reference driver, which is essentially a repeat of the RDS output A reference generator circuit. The values have been adjusted to produce a 400 Hz synchro signal of suitable amplitude. Figure D-8 shows the schematic diagram of the reference driver.

RDS Azimuth Allignement

All azimuth signals for all the accessible radar signals onboard the M.V. Arctic, are generated from two antennas. Since the synchro transmitters in each antenna has been arbitrarily alligned when installed, changing from the Decca signals to the Sperry signals will introduce an image angular shift unless the synchro signals have been alligned.

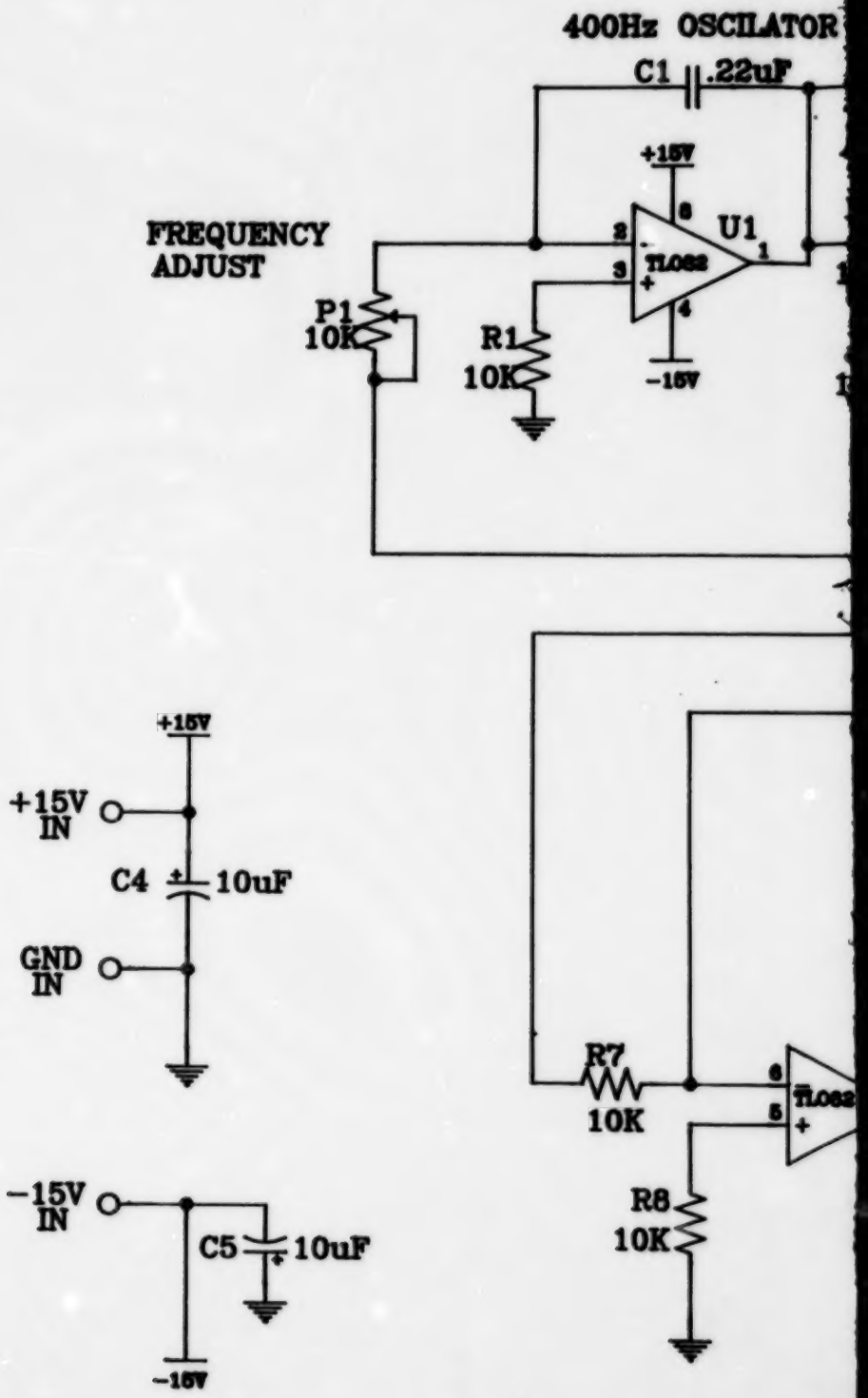
The allignement of the synchro signals has been implemented with two synchro transformers mounted in the SINSS console, at the back of the RDS. Once the display was activated, tagets were chosen and the images for the two radar systems were alligned to match.



CHL ANTENNA
SYNCHRO REFERENCE DRIVER

Figure D-7
CHL Antenna Synchro Reference Driver

SYNCHRO R


400Hz OSCILATOR
C1 .22uF
+15V
FREQUENCY ADJUST
P1 10K
R1 10K
U1
TL082
-15V
+15V IN
C4 10uF
GND IN
-15V IN
C5 10uF
-15V
R7 10K
R8 10K

O REFERENCE DRIVER

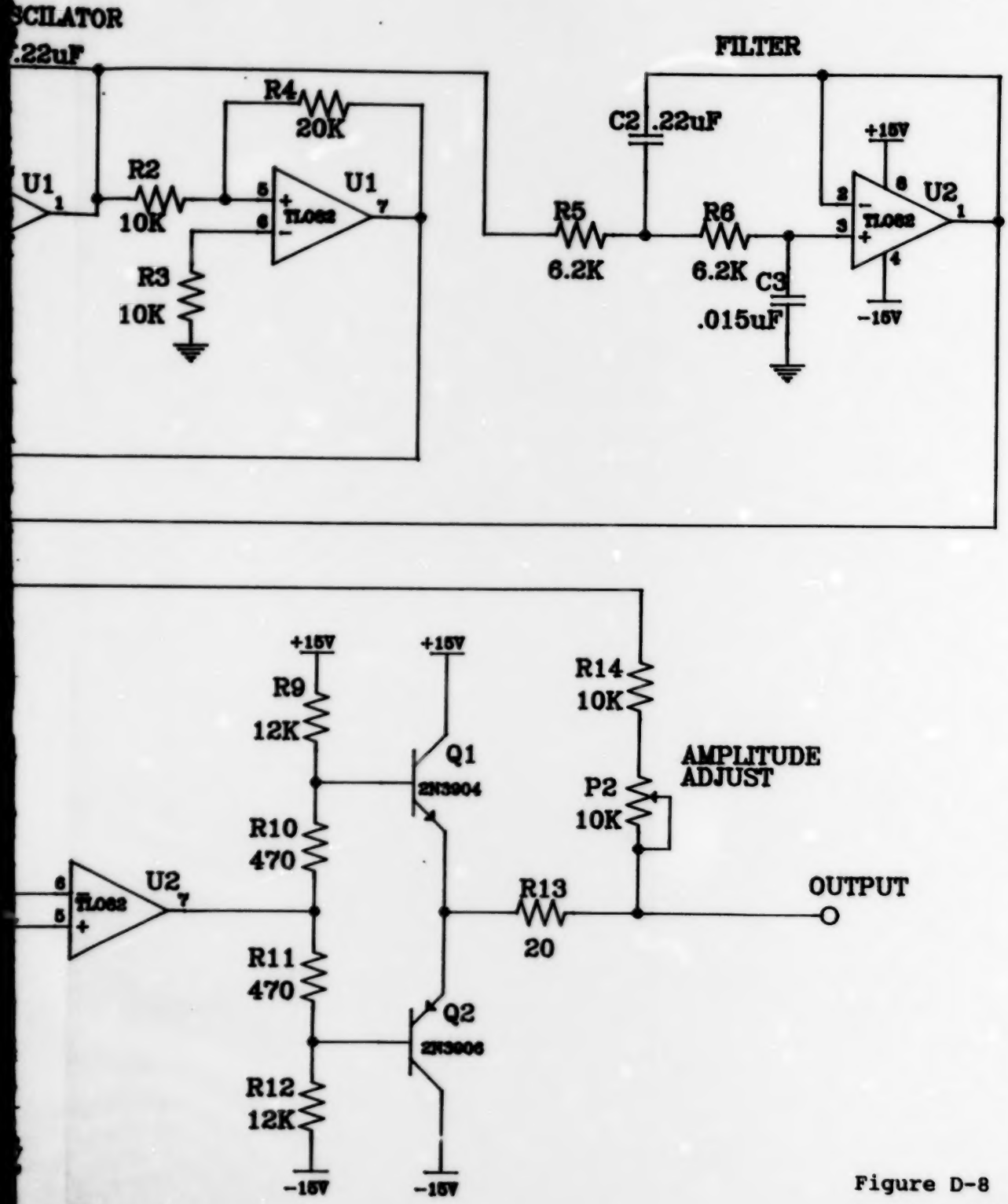


Figure D-8
Synchro Reference Driver